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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND ALEX. RICHARDSON.

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CULVER STREET WORKS, COLCHESTER.
ON ADMIRALTY AND WAR OFFICE LISTS.
ENGINES for Torpedo Boats, Yachts, Launches.
BOILER FEED PUMPS.
See advertisement page 18.
PATENT WATER-TUBE BOILERS.
AUTOMATIC FEED REGULATORS.
And Auxiliary Machinery as supplied to the Admiralty. 2179

Dredging Plant
OF ALL DESCRIPTIONS.
FLOATING CRANES. COAL BUNKERING VESSELS.
Werf Conrad, HAARLEM, HOLLAND.
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See half-page Advert. last week and next week. 1382

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GEORGE RUSSELL & CO., LTD., Motherwell. 1867

STEEL TANKS, PIPES, GASHOLDERS, &c.
Thos. Piggott & Co., Limited,
BIRMINGHAM. 1241
See Advertisement last week, page 19.

Spencer-Hopwood & Kirke
PATENT BOILERS 1293 *See Page 71.*
Sole Makers: SPENCER-BONECOURT, LTD., Parliament Mansions, Victoria St., London, S.W.

Tank Locomotives.
Specification and Workmanship equal to Main Line Locomotives.
R. & W. HAWTHORN, LESLIE & CO. LTD., ENGINEERS, NEWCASTLE-ON-TYNE. 1864

P. & W. MacLellan, Ltd.,
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MANUFACTURERS OF RAILWAY CARRIAGES AND WAGONS OF EVERY DESCRIPTION.
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LIMITED,
Hammers, Presses, Furnaces,
COVENTRY. 610

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1357
S. H. HEYWOOD & CO., LTD., REDDISH.

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SPECIALISTS
in the
SALE AND VALUATION
of
PLANT AND MACHINERY
and
ENGINEERING WORKS.
11, BILLITER SQUARE, E.C.3. 1834

Iron and Steel
Tubes and Fittings.
Sole Licensees in Great Britain for the manufacture of "Armco" Rust and Corrosion Resisting Iron Tubes. 317
The Scottish Tube Co., Ltd.,
HEAD OFFICE: 34, Robertson Street, Glasgow.
See Advertisement, page 77, March 14.

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PASSENGER AND CARGO STEAMERS.
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Worm Wheels cut up to 13 ft. diam.
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Builders of RAILWAY CARRIAGES, WAGONS ELECTRIC CARS, and EVERY OTHER DESCRIPTION OF RAILWAY and TRAMWAY ROLLING STOCK.
Makers of WHEELS and AXLES, RAILWAY PLANT, FORGINGS, SMITH WORK, IRON & BRASS CASTINGS, PRESSED STEEL WORK OF ALL KINDS. Od3382
Reg. Office and Chief Works: Motherwell. London Office: 52, Great St. Helens, Bishopsgate, E.C. 3.

OIL FUEL APPLIANCES,
Systems
PRESSURE, AIR, STEAM
For Boilers of all types.
KERMODES LIMITED,
35, The Temple, Dale Street, Liverpool.
Naval Outfits a Speciality, also for Merchants Ships, for Factories, Locomotives, and Industrial Process Furnaces of all kinds.
Supplied to the British and other Governments.
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Locomotives Tank Engines
designed and constructed by
MANNING, WARDLE AND COMPANY, LIMITED.
Boyne Engine Works, Leeds. Od 2487
See their Illus. Advertisement, page 91, last week.

Gearing of all Descriptions.
GEAR WHEELS up to 10 ft. diameter.
FLY ROPE and SPUR DRIVING WHEELS up to 28 ft. diameter.
BRICK and CLAYWORKING MACHINERY of all kinds.
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MAKERS of WHEEL and AXLES of all kinds
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Patents and Trademarks:—
Inventors Advice, Handbook and Consultations free.—KINGS PATENT AGENCY, LTD. (P. T. King, Director), 146a, Queen Victoria Street, London. 36 years' refs. 1209

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John Kirkaldy, Ltd.,
London Office: 101, LEADENHALL ST., E.C.3.
Works: BURNT MILL, near HARLOW, ESSEX.
Makers of
Evaporating and Distilling Plants.
Refrigerating and Ice-making Machinery.
Feed Water Heaters.
Evaporators.
Fresh Water Distillers.
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Combined Circulating and Air Pumps.
Auxiliary Surface Condensers,
&c., &c. 1586

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GENERAL CONSTRUCTIONAL ENGINEERS,
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STILLS, PETROL TANKS, AIR RECEIVERS, STEEL CHIMNEYS, RIVETED STEAM AND VENTILATING PIPES, HOPPERS, SPECIAL WORK, REPAIRS OF ALL KINDS.

IRON & STEEL
Tubes AND Fittings
AND
Steel Plates.

STEWARTS AND LLOYDS, Ltd.
GLASGOW BIRMINGHAM - LONDON.
See Advertisement, page 50. 1872

Peter Brotherhood Ltd.,
PETERBOROUGH.
STEAM ENGINES AND TURBINES.
GAS AND OIL ENGINES.
AIR COMPRESSORS.
REFRIGERATING PLANT. 1475
See Advertisement, page 53, March 14.

The Glasgow Railway Engineering Company,
GOVAN, GLASGOW. LTD.,
London Office—12, Victoria Street, S.W.
MANUFACTURERS OF
RAILWAY CARRIAGE, WAGON & TRAMWAY WHEELS & AXLES.
CARRIAGE & WAGON IRONWORK, also
CAST-STEEL AXLE BOXES. 1945

For Sale, Motor Generator, by Lancashire Dynamo Co. Ltd., 1920, Comprising, 480 volt, D.C. Motor, coupled to 105 volt, 830 ampere compound interpole Generator, complete with Switchboard.
THE PHŒNIX ELECTRICAL CO., LTD., 17, Oswald Street, Glasgow. C 475

The Royal Air Force REQUIRES ELECTRICIANS, WIRELESS OPERATORS and POWER STATION TRADESMEN. Age limits: ex-service men 18 to 30; non ex-service 18 to 26. Pay from 24s. 6d. to 38s. 6d. per week on enlistment, and all found. Allowance for wife and children to men 26 and over. —Write, stating age, or call:—INSPECTOR OF RECRUITING, R.A.F., 4, Henrietta Street, Covent Garden, London, W.C.2. C 965

For Your Repairs or any
SPECIAL MACHINERY, try
THOMAS HUNT & SONS,
Albion Ironworks,
Bridge Road West, Battersea, S.W. 11.
Est. 1864. 2007

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Hurst, Nelson & Co., Ltd.
THE GLASGOW ROLLING STOCK AND PLANT WORKS, MOTHERWELL. Od 3383

Electric Lifts
(UP TO 35 TONS.)
1357
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BRITISH and FOREIGN. Moderate charges, Long and varied practical Engineering experience valuable to Inventors. Formerly many years contributor of Patents Abstracts for "The Engineer" & "The Times."—Thanet House, Temple Bar, London, W.C.2.

Telegrams: "Epa," London.
Telephone: 7424 Central.
E. P. Alexander & Son.
CHARTERED PATENT AGENTS,
306, High Holborn, London, W.C. 1. 585
PATENTS. DESIGNS. TRADE MARKS.

Metallography with the Super-microscope. Paper read by Dr. Rogers, November 13th, before the Sheffield Metallurgical Society. See page 20.—F. DAVIDSON & CO., 29, Great Portland St., London, W.1. 2009

Royles Limited,
ENGINEERS, IRLAM, MANCHESTER.
FEED WATER HEATERS, CALORIFIERS, EVAPORATORS, CONDENSERS, AIR HEATERS, } ROWS PATENTS.
Merrill's Patent TWIN STRAINERS for Pump Suctions.
SYPHONIA STEAM TRAPS, REDUCING VALVES.
High-class GUNMETAL STEAM FITTINGS.
WATER SOFTENING and FILTERING. 5723

YARROW & CO. (1922), LTD., GLASGOW.
LAND AND MARINE
YARROW BOILERS. 1553

Matthew Paul & Co., Ltd.,
LEVENFORD WORKS, Dumbarton. 1483
See Full Page Advt., page 61, Feb. 29.

Forgings.
Walter Somers, Limited,
HALESOWEN. 7116

Taylor & Challen Presses
For Production of SHEET METAL WORK, COINAGE, CARTRIDGES AND GUNPOWDER.
Foundry, Works, and Showrooms: BIRMINGHAM.
See advert., page 10, Feb. 29. 8195

Head, Wrightson & Co.,
LIMITED.
See Advertisement page 61. 2462

Railway Switches and Crossings
T. SUMMERSON & SONS, LIMITED, DARLINGTON. 2006

DAVID BROWN & SONS (Hudd.) Ltd.
Lockwood Huddersfield.
HIGH CLASS
Machine Cut Gearing
FOR EVERY PURPOSE. 1440

HEAT INSULATION.
CELITE PRODUCTS CORPORATION,
Windsor House, Westminster, S.W.1. 1675
See our Illustrated Advertisement, March 14.

E. J. Davis, M.I.Mech.E., Gas Engines Inspected, Tested and Reported upon. Over 26 years' experience. Tel.: Maryland 1736 & 1737. Wire: "Rapidising, London." —Great Eastern Road, Stratford, E.15. 1794

Locomotive Traversers
(ELECTRIC).
1357
S. H. HEYWOOD & CO., LTD., REDDISH.

Rosser and Russell, Ltd.,
MECHANICAL ENGINEERS,
QUHEN'S WHARF, HAMMERSMITH, W.
Undertake SPECIAL MACHINE WORK of any description.
WELL EQUIPPED SHOP.
LATHE WORK up to 10 ft. diameter.
'Phone: Hammersmith 31, 96. 9211

Centrifugals.
Pott, Cassels & Williamson,
MOTHERWELL, SCOTLAND.
1676
See half-page Advertisement, page 68, March 14.

The Manchester Steam Users' ASSOCIATION.

For the prevention of Steam Boiler Explosions and for the attainment of Economy in the Application of Steam. 9, MOUNT STREET, MANCHESTER.

Chief Engineer: C. B. STROMEYER, M.I.C.E.

Founded 1854 by Sir WILLIAM FAIRBAIRN.

Certificates of Safety issued under the Factory and Workshops Act, 1901. Compensation for Damages and Liabilities paid in case of Explosions. Engines and Boilers inspected during construction. 2005

TO ENGINEERS, MACHINISTS, AND OTHERS.

The London Board of Shechetа

OFFER THREE PRIZES for a Machine or other Apparatus for the purpose of casting animals to be slaughtered for food, the essentials to be simplicity, expedition and without suffering to the animals.

First Prize £50; Second £35; Third £15.

The Board to have the right to acquire for a sum not exceeding £500 the patent or patents and all rights thereunder of any machine or apparatus submitted.

Any further particulars may be obtained from
The SECRETARY
to the London Shechetа Board,
Vestry Room, Henesge Lane,
Bevis Marks, E.C. 3,

to whom drawings with specifications must be sent under cover not later than the 1st June, 1924, the Board not to be liable for the safe custody or return of same. D 256

Correspondence Courses for

Inst.Civil Engrs., Inst.Mech.E., London Univ. (Matric., Inter., B.Sc.), and All ENGINEERING EXAMINATIONS personally conducted by Mr. TREVOR W. PHILLIPS, B.Sc. (Honours), Assoc. M.Inst.C.E., M.R.S.I., F.R.S.A., etc. Also Day Tuition in Office. Excellent results at all Exams. Courses may commence at any time, and all Students receive individual tuition.—For full particulars apply to 8/11, TRAFFORD CHAMBERS, 58, SOUTH JOHN STREET, LIVERPOOL. 1993

Engineering Salesmanship

and SALES MANAGEMENT.—Write for brochure describing our special Course of Training for posts of unlimited scope in this lucrative field.—DIRECTOR, Institute of Engineering Salesmanship, 333, Oxford Road, Manchester. 1879

TENDERS.

COUNTY BOROUGH OF WOLVERHAMPTON.

WATERWORKS UNDERTAKING.

15 in. and 12 in. CAST IRON TRUNK MAINS.

The Wolverhampton Corporation is prepared to receive

Tenders for Providing and

LAYING about 5400 yards of 15 in. and 2940 yards of 12 in. CAST IRON WATER MAINS, and Executing other Work in connection therewith, from Contractors who pay to the whole of their employees such remuneration and observe such hours of employment as are recognised by the Employees' Unions and Associations of Employers in the several localities where the work is done.

A copy of the Specification, Quantities, and Form of Tender may be obtained from Mr. H. A. B. WOODWARD, Waterworks Engineer, Town Hall, Wolverhampton, upon payment of the sum of £2 sterling, which amount will be returned to each Contractor who submits a *bona fide* Tender, but not otherwise.

Each Tender must be enclosed in a sealed envelope, addressed to "The Chairman of the Water Committee," and endorsed "Trunk Mains," and delivered at my Office on or before Ten a.m. on Tuesday the 15th day of April, 1924.

The right to decline the lowest or any Tender is reserved to the Corporation.

F. H. WARBRECK HOWELL,
Town Clerk.

Town Hall, Wolverhampton.
5th March, 1924. D 178

METROPOLITAN WATER BOARD.

MAIN.—KEMPTON TO CRICKLEWOOD.

TENDER FOR SECTION NO. 1—LAYING AND JOINTING 48 in. CAST IRON AND 53 in. STEEL PIPES AND CONTINGENT WORKS FROM KEMPTON TO GREENFORD.

The Metropolitan Water Board invite

Tenders for the Laying and

JOINTING of about 7¼ miles of 48 in. diameter CAST IRON WATER MAIN and the laying of about 480 yds. of 52 in. STEEL PIPES in subways, between the Board's works at Kempton and Windmill Lane, north of Greenford Valve House in the County of Middlesex.

Drawings, Conditions of Contract and Specifications may be inspected without payment of a fee at the Offices of the Board, Chief Engineer's Department (Room 201) on and after 20th March, 1924.

Forms of Tender, Conditions of Contract, Specification, Bills of Quantities and Schedules of Prices, together with drawings and a spare copy of the Bills of Quantities and Schedules of prices, may be obtained on and after 31st March, 1924 from Mr. HENRY H. STILGOE, M.Inst.C.E., the Chief Engineer, on production of an official receipt for the sum of £30, which sum must be deposited with the Accountant to the Board, and will be returned on receipt of a *bona fide* Tender, accompanied by all the above-named documents and drawings (with the exception of the spare copy of the Bills of Quantities and Schedules of Prices which may be retained by the Tenderer). Such payments and applications must be made between the hours of Ten a.m. and 4.30 p.m. (Saturdays Ten a.m. and Twelve noon).

Cheques must be made payable to the "Metropolitan Water Board," and not to individuals.

Tenders enclosed in sealed envelopes, addressed to "The Clerk of the Board, Metropolitan Water Board, New River Head, Clerkenwell, E.C. 1," and endorsed "Tender for Section No. 1, Kempton to Cricklewood Main," must be delivered at the Offices of the Board not later than Ten a.m. on Monday, 28th April, 1924.

The Board do not bind themselves to accept the lowest or any Tender.

G. F. STRINGER,
Clerk of the Board.

Offices of the Board,
New River Head,
Clerkenwell, E.C. 1.
8th March, 1924. D 177

THE HIGH COMMISSIONER FOR INDIA is prepared to receive

Tenders for the Supply

of:—
TWIN SCREW CABLE STEAMER, 236 feet long, 14 feet draught, speed not less 12 knots.

Forms of Tender may be obtained from the Director-General, India Store Department, Branch No. 16, Belvedere Road, Lambeth, S.E.1, and Tenders are to be delivered at that Office not later than Two o'clock on Tuesday, 22nd April, 1924.

S. PADDON,
Acting Director-General. D 258

TRINITY HOUSE, LONDON.

TENDER FOR STEEL OIL DRUMS.

Tenders are Hereby Invited

for the SUPPLY and DELIVERY to Trinity Wharf, Neyland, South Wales, of 100 FIVE GALLON STEEL OIL DRUMS.

Forms of Tender and Specifications with all necessary information may be obtained on application to Trinity House, Tower Hill, London, E.C. 3, between the hours of 10.30 a.m. and 4.30 p.m.

No Tender will be considered that is not made on the form provided.

Tenders in sealed envelopes, marked outside "Tender for Steel Oil Drums," are to be addressed to The Secretary, and delivered to Trinity House not later than Ten a.m. on Thursday, 3rd April, 1924.

The Corporation do not bind themselves to accept the lowest or any Tender.

M. K. SMITH,
Secretary. D 227

GREAT NORTHERN RAILWAY (IRELAND).

TO BRIDGE CONTRACTORS.

The Directors are prepared to received

Tenders for the Supply and

ERECTION of a STEEL SUPERSTRUCTURE for an Overline Bridge.

The Drawings and Specification may be inspected at the Engineer's Offices, Dublin and Belfast, and copies of same, together with Bills of Quantities and Forms of Tender, may be obtained from the undersigned on payment of Two Guineas, which will be refunded on receipt of a *bona fide* Tender, accompanied by the Drawings.

Tenders, made out on forms supplied by the Company, should be delivered, under sealed cover, endorsed "TENDER FOR BRIDGEWORK," not later than Ten a.m. on Thursday, 10th April, 1924.

The Directors do not bind themselves to accept the lowest or any Tender.

J. B. STEPHENS,
Secretary.

Amiens Street Station,
DUBLIN, 20th March, 1924. D 247

THE SOUTH INDIAN RAILWAY COMPANY, LIMITED, are prepared to receive

Tenders for the Supply of:—

CAST IRON PIPES.

Specification and form of Tender will be available at the Company's Offices, 91, Petty France, Westminster, S.W.1.

Tenders, addressed to the Chairman and Directors of the South Indian Railway Company, Limited, marked "Tender for Cast Iron Pipes," must be left with the undersigned not later than Twelve Noon on Friday, the 4th April, 1924.

The Directors do not bind themselves to accept the lowest of any Tender.

A charge, which will not be returned, will be made of 2s. 6d. for each copy of the Specification.

Copies of the drawings may be obtained at the Offices of Messrs. ROBERT WHITE & PARTNERS, Consulting Engineers to the Company, 3, Victoria Street, Westminster, S.W.1.

W. B. REYNOLDS,
for Managing Director.

91, Petty France, S.W.1.
14th March, 1924. D 223

METROPOLITAN BOROUGH OF HACKNEY.

ELECTRICITY DEPARTMENT.

FOR SALE.

The Council of the Metropolitan Borough of Hackney invite

Tenders for the Purchase,

DISMANTLING and REMOVAL Complete or Separately, of the undermentioned STEAM ENGINES and CONDENSING PLANT, which may be inspected at the Millfields Road Power House, Clapton, E. 5, at any time by appointment.

ITEM I.—One Belliss & Morcom Triple Expansion double-acting Engine, 1000 I.H.P. running condensing 26 inches vacuum, 175 lbs. stop valve, 310 R.P.M.

ITEM II.—One Willans & Robinson Triple Expansion single-acting central valve Engine, 500 I.H.P. running condensing 26 inches vacuum, 175 lbs. stop valve, 310 R.P.M.

ITEM III.—One Willans & Robinson Triple Expansion single-acting central valve Engine, 500 I.H.P. running condensing 26 inches vacuum, 175 lbs. stop valve, 310 R.P.M.

ITEM IV.—One Cole, Marchant & Morley Surface Condenser, to deal with 30,000 lbs. steam, complete with motor-driven Edwards Air Pump and Circulating Water Pump, 1900 gallons per minute.

ITEM V.—One Cole, Marchant & Morley Surface Condenser, to deal with 15,000 lbs. steam, complete with motor-driven Edwards Air Pump and Circulating Water Pump, 950 gallons per minute.

ITEM VI.—Baker's Oil Separators and Interconnecting pipes and valves, as seen at site.

All the plant is in excellent condition, including many spare parts.

Further particulars, Tender Form, and order to view can be obtained from the Borough Electrical Engineer, 206, Mare Street, Hackney, E. 8.

Tenders must be placed in an envelope, sealed with sealing wax, and endorsed "Plant for Disposal," and delivered by the person tendering, or by his authorised representative, to the Chairman at a special meeting of the Establishment and General Purposes Committee of the Council, to be held at the Town Hall, at Seven o'clock p.m. on Wednesday, the 16th April, 1924, or may be sent by post in a registered envelope, addressed to the Chairman, so as to be delivered to him not later than the time named above.

The Council do not bind themselves to accept the highest or any Tender.

R. H. R. TEBB,
Town Clerk.

Town Hall, Hackney, E. 8.
13th March, 1924. D.212

The Director-General,

India Store Department, Branch No. 16, Belvedere Road, Lambeth, S.E.1, REQUIRES:—

WHEELS AND AXLES.

Tenders due on the 1st April, 1924.
Tender Forms obtainable from above. D 257

LODGE HILL, near CHATHAM.

Tenders are Invited for

the PURCHASE and REMOVAL of the undermentioned TIMBER-FRAMED HUTS, now at Chattenden Farm, Lodge Hill, and of approximate floor measurements as follows:—

4 No. — 80 feet by 16 feet.
1 No. — 31 „ by 29 „
1 No. — 61 „ by 29 „
1 No. — 61 „ by 16 „

Tenders to be delivered not later than Noon on 4th April, 1924, to SUPERINTENDING CIVIL ENGINEER, H.M. Dockyard, Chatham, from whom full particulars and Forms of Tender may be obtained. D 253

APPOINTMENTS OPEN.

Works Manager for London

REQUIRED to control large factory nearly 2000 employees; must have had personal experience in negotiating with organised labour on a large scale and be accustomed to deal with labour disputes in a conciliatory way. Must be energetic, well educated and of good personality. Age not exceeding 40. Candidature must include organising, managerial and disciplinary abilities and be able to maintain an economic output in relation to a large wages bill. An adequate salary to competent business man meeting above requirements and holding similar appointment. Applications will not be divulged. State detailed particulars of training, qualifications and experience to B, c/o LILE'S Advtg. Offices, 4, Ludgate Circus, London, E.C.4. D 249

COUNTY BOROUGH OF BURNLEY.

ASSISTANT ENGINEERING DRAUGHTSMAN IN GAS DEPARTMENT.

The Burnley Town Council invite

Applications for the Position

of ASSISTANT ENGINEERING DRAUGHTSMAN in the Gas Department. Applicants must be competent to design Gas Works Plant.

Applications, stating age, present occupation, previous experience, technical qualifications and salary required, accompanied by copies of three recent testimonials, and endorsed "Draughtsman," must reach the undersigned not later than Friday the 28th instant.

COLIN CAMPBELL,
Town Clerk.

Town Hall, Burnley.
18th March, 1924. D 240

UNIVERSITY COLLEGE OF SWANSEA.

The Council invites

Applications for the Post of

ASSISTANT LECTURER in Metallurgy. Salary, £300 per annum. The appointment will date from the 22nd April, 1924.

Further particulars may be obtained from the undersigned, by whom applications must be received on or before the 31st March 1924.

EDWIN DREW,
Registrar.

Singleton Park, Swansea. D 242

India.—An English Firm of

Engineers in India REQUIRE an ASSISTANT MECHANICAL ENGINEER.

Applicants should have had workshops and drawing office experience, and be capable of preparing drawings and estimates for Mill Gearing and General Mechanical Engineering Work.

Age 25 to 28. Must be a bachelor.

Write, giving full particulars of training and references, to Z.Y. 971, c/o DEACONS, Leadenhall Street, London, E.C. D 255

Erection Superintendent

REQUIRED, accustomed to deal with Gasholders, Gas Plant, Tanks and Pipe work.—State age, experience and salary required, to THOS. PIGGOTT & CO., LTD., Spring Hill, Birmingham. D 261

Wanted, Immediately, an

ASSISTANT MARINE ENGINE DRAUGHTSMAN, one used to all types of Steam Machinery and Installations up to 1000 I.H.P. State age, experience and salary expected.—Apply, PHILIP & SON, LTD., Dartmouth. D 268

Assistant Engineer

REQUIRED for the PUBLIC WORKS DEPARTMENT of the GOVERNMENT of the STRAITS SETTLEMENTS for three years' service with prospect of permanency. Salary $400 a month rising to $800 a month by annual increments of $25 a month, plus a strictly temporary non-pensionable allowance of 10%. The Government rate of exchange is now 2s. 4d. to the dollar, but the purchasing power of the dollar in Malaya is at present considerably less than that of 2s 4d. in the United Kingdom. Free passages provided. Candidates, aged 26 to 35, unmarried, must be Associate Members of the Institution of Civil Engineers, and have had at least three years practical experience (exclusive of pupilage) as Engineering Assistants under an Engineer who is a Member of the Institution of Civil Engineers.—Apply at once, by letter, giving brief details of qualifications and experience, to THE CROWN AGENTS FOR THE COLONIES, 4, Millbank, London, S.W. 1, quoting M/12617. D 266

Wanted, for Large Marine

Engineering Establishment ASSISTANT COST ESTIMATOR.

Address, stating age, experience and salary expected, D 267, Offices of ENGINEERING.

Junior Assistants

REQUIRED.—(1) For experimental work upon instruments (quote A. 36). (2) For elasticity research laboratory (quote A. 37). Candidates should possess Hons. Degree in Engineering or Physics and should have had works or research experience. Salary, £175 a year, plus Civil Service bonus (giving present total of £379) on scale £175—15—£235, plus bonus. Ex-Service men preferred.—Apply, SUPERINTENDENT, Royal Aircraft Establishment, South Farnborough, Hants. D 235

Engineer and Correspondent,

with thorough experience in Plenum Heating and Ventilation. Age, experience and salary required to—BOX 1255, c/o MATHER & CROWTHER, Ltd., 10, New Bridge Street, E.C. 4. D 213

Electric Power Supply Engineers.

—Applicants are informed that the Junior position advertised on January 11th, under BOX No. C 535, has been filled. D 235

Draughtsman (Assistant).—

Experienced in crane design and details, constructional work, etc.—Apply, by letter, with full particulars, experience, age, salary required, RICHARD C. GIBBINS & CO., Berkley Street, Birmingham. D 241

Draughtsman, not under

thirty years of age; particulars as to experience and salary.—VAUGHAN CRANE CO., LTD., Openshaw, Manchester. D 244

Wanted, Thoroughly

Experienced DRAUGHTSMAN for design and shop drawings of Bridgework and general Steelwork to Engineers' specifications. State age, experience and salary required.—Address, D 158, Offices of ENGINEERING.

Draughtsman Required, City

Office, good general engineering knowledge, including cranes, conveyors or similar work.—Address, stating age, particulars of experience and salary required, D 216, Offices of ENGINEERING.

Senior Draughtsmen Required

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THE GREAT LAKE HYDRO-ELECTRIC SCHEME, TASMANIA.

THE year just closed has marked a stage in the history of the Hydro-electric Department of the State of Tasmania, as it has seen the practical conclusion and official opening of the Great Lake hydro-electric project which was responsible for bringing the department into existence. On January 18, 1923, His Excellency the Governor General of Australia, Lord Forster, P.C., G.C.M.G., officially declared the works open and started up the most recently-installed units, though much of the plant has been forced into service as soon as completed, the first units being started up in 1916.

The State of Tasmania is one of the few countries in which comprehensive surveys of water resources have been made. Even here, however, the survey is not complete, but data are available showing that sources of power aggregating about 400,000 h.p. have been located beyond that which has now been developed, while estimates run to an additional 130,000 h.p. less definitely investigated. As the amount now developed runs to close upon 70,000 h.p. the total for the State is approximately placed at 600,000 h.p. In the review of "Water Power in the British Empire," by Sir Dugald Clerk and Professor A. H. Gibson, it is stated that the State should be capable of developing a relatively large amount of power since the rainfall exceeds 100 in. per annum over a large area of the mountains of the west. This perhaps will convey a rather exaggerated idea of the possibilities, for the area on which there is precipitation on this scale is only about 800 sq. miles, confined practically to two watersheds, in which sites have been located provisionally for 85,000 h.p.; power to the extent of 10,000 h.p. is now developed in this area. The greater part of the island has a more moderate rainfall; on the east side the areas showing more than 50 in. are small, while in the centre belt 30 in. to 40 in. is a high figure. On the western section probably more than half records falls of over 60 in.

The central portion of Tasmania consists of an extensive plateau varying in elevation from 2,000 ft. to 4,000 ft. above mean sea level. On the west it is bounded by mountain ranges, whose peaks reach to a height of 5,000 ft. For the greater portion of its northern, eastern and southern edges, the plateau ends in a scarp, dropping rapidly from 2,000 ft. to 3,000 ft. to the lowlands. In geological structure it consists of plains of basalt or diabase intersected by stony ridges of the latter material, which are sparsely covered with stunted timber. The areas between these ridges are for the most part devoid of timber and are usually marshy in character. Lakes are numerous; some of them are of glacial origin, but the larger ones are probably subsidence basins. The map given in Fig. 1 shows how the central plateau is studded with lakes in this way. These lakes give rise to numerous streams, which flow through deep gorges cut in the edge of the plateau to the coastal plains in the north or the tributaries of the River Derwent in the south.

The plateau, although possessing a plentiful rainfall, has a severe winter climate, heavy falls of snow being frequent. Difficult of access and far from markets, and for the most part barren or marshy, this vast area of country has until recently been of little economic value, serving only as a summer pasture for stock and a hunting ground for fur trappers. The fact that such a large proportion of the area of the State is incapable of closer settlement, and has produced neither minerals nor timber of marketable value, has undoubtedly restricted the progress of the State. For years no new industries of importance had been established, and the younger members of the community were being forced to seek employment on the mainland, with the result that the population remained practically stationary.

It has now for some time been recognised that the very circumstances which combine to render the plateau unsuitable for agricultural settlement, viz., the snow-fed lakes and marshes, the high altitude, and the steep approaches for transport routes, also constitute the essential factors necessary for the successful development of a number of hydro-electric schemes, capable of furnishing cheap power for industries, situated on the many excellent deep-water harbours on the coast. Instead of an area of little value, forming a barrier to communication between other settled portions of the State, the plateau has now become a most valuable asset to the industrial development of Tasmania.

The Great Lake, which, as shown in Fig. 1, is in a very central position, is the largest and most important of the plateau lakes. It is shown to a larger scale in Fig. 2, and is the first of the plateau lakes to be utilised for the development of power. It gives rise to the Shannon River flowing in a general southerly direction to the River Derwent. To westward, and roughly parallel to the River Shannon, flows the River Ouse. At a point about 5 miles to the west of the Great Lake the River Ouse is at an elevation of 120 ft. above the lake, and the scheme now concluded embodied the construction of a canal to divert the water of the Ouse into the Great Lake so as to take advantage of the greater supply afforded by the additional catchment area.

The works involved are outlined in Fig. 2, which shows the Ouse diversion on the west, while a dam has been constructed as marked across the outlet of the Great Lake, providing storage for the water derived from its own catchment together with that diverted from the Ouse River. The water released from the lake flows for a distance of 4 miles down the River Shannon, and is then diverted by a weir into a canal 3½ miles in length into a natural lagoon. Between this lagoon and the site of the power station at Waddamana, situated on the bank of the River Ouse, there is a difference of elevation of 1,120 ft., and this drop is utilised by carrying the water in a series of wood and steel pipes from the lagoon to the power station. The profile given in Fig. 3, page 356, shows the elevations and distances from the gathering grounds to the power station.

The scheme originated as follows: In the year 1908 a Melbourne company, the Complex Ores Company, Limited, approached the Government of Tasmania with a view to induce them to harness some of the Tasmanian water power, and make it available for the company for the electrolytic treatment of complex zinc ores by the "Gillies" patents owned by the company. The Government of the day found itself unable to embark on the project, but recommended the granting of a concession to the company to enable it to undertake the development of the power itself. The concession was granted by Parliament in 1909, and a separate company, the Hydro-Electric Power and Metallurgical Company, Limited, was formed by the parent Complex Ores Company to deal with the Tasmanian enterprise.

The new company started active operations in 1911 on a scheme having a power station capacity of 6,000 k.v.a. From the outset considerable difficulties were met with, the winter of 1912 proving one of the worst on record. The company then found it desirable to increase the power station capacity to 8,100 k.v.a., but unfortunately encountered a severe financial stringency resulting from the two Balkan Wars, when it went to the market for more money. Notwithstanding a favourable report upon the scheme by Mr. Alfred Dickenson, M.Inst.C.E., the company found itself unable to raise the necessary funds to complete the work. After negotiations, in October, 1914, the company disposed of its concession and works to the State of

Fig. 1.

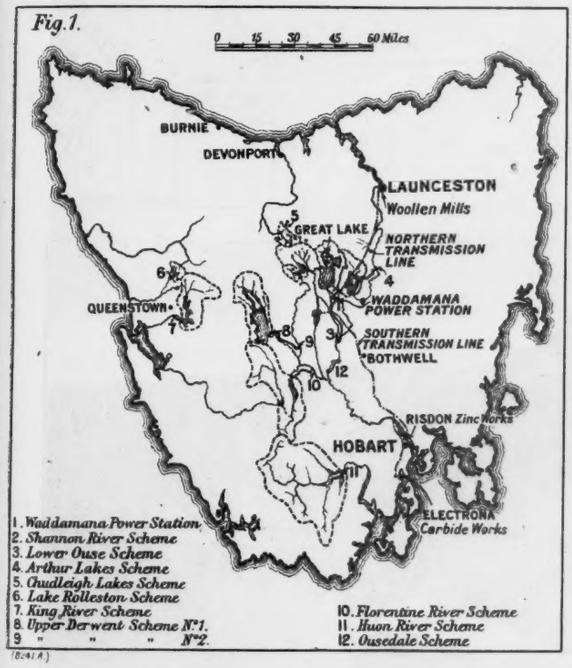


Fig. 2.

Tasmania, the decision of the Government and Parliament to purchase the scheme being largely influenced by a report by Mr. Evan Parry, the Chief Electrical Engineer to the New Zealand Government, who strongly advised the purchase. Among the important reasons which influenced the Government's decision was that hydro-electric development would enable new industries to be started in the country, and a check would thus be offered to the emigration of the younger section of the population.

Immediately the State became possessed of the scheme, the Government engaged the services of Mr. J. H. Butters, C.M.G., M.I.E.E., the then engineer-in-chief of the Hydro-Electric Power and Metallurgical Company. Mr. Butters had been responsible for the design and construction of the scheme from its inception, and he was appointed as chief engineer and general manager of the undertaking, and a new Government Department—the Hydro-Electric Department—was called into existence for the purpose of completing the scheme and operating it after completion.

This department resumed constructional operations in October, 1914, and in spite of enormous difficulties and delays caused by the war the original instalment of the work was completed and two units, each of 5,000-h.p. capacity, put in operation in May, 1916.

Early in 1917, the plant was supplying about 2,000 h.p. to the City of Hobart and suburbs for lighting, power and tramway operation, and also supplying about 3,500 h.p. to the Hydro-Electric Power and Metallurgical Company for the manufacture of carbide at its Electrona works. The Electrolytic Zinc Company of Australia, Limited, was also operating its experimental plant and had entered into a contract with the Government of Tasmania for the supply of a block of 4,000 h.p., to be gradually increased by successive blocks to a total of 30,000 h.p. This necessitated immediately increasing the power station capacity to 18,000 h.p. by the addition of a new pipe line and the installation of No. 3 unit of 8,000 h.p., the foundations for which had already been provided. The canal had originally been constructed for a capacity of 28,000 h.p., and provision had also been made for a second circuit on the transmission line towers.

In addition to the further blocks of power required by the Electrolytic Zinc Company, further demands for power from Hobart and surrounding districts, and also from Launceston, necessitated a large extension of the scheme, and in 1919 a construction programme was entered upon to bring the continuous capacity of the scheme up to 58,000 h.p. This work has now been successfully completed and put into operation, the last turbine being started, as already stated, up by His Excellency the Governor-General (Lord Forster) on January 18 of last year. Through the courtesy of the chief engineer and general manager, Mr. J. H. Butters, we are now able to give a description of the completed scheme and details of its more important features. It should be remarked that since inauguration in 1916 power has been generated continuously and the enlargements have been made without interrupting the service. When it is realised that the capacity has been increased elevenfold in seven years, it will be understood that a well-thought-out programme and excellent organisation were essential, and it is a high tribute to Mr. Butters and his staff that such work should have proved possible in the course of the recent years of unstable conditions.

The position of the Great Lake has already been alluded to. The boundaries of the lake itself and the boundaries of its own catchment area and of those areas which can be made tributary to it, are shown in Fig. 2. The catchment directly draining into the Great Lake has an area of 153 sq. miles, and is surrounded by hills rising at the northern end to about 1,000 ft. above the lake. The annual rainfall varies from 30 in. at the southern end to over 60 in. at the northern end. To the westward of the Great Lake lies the upper portion of the catchment of the Ouse River and its tributary the James, having an area of 107 sq. miles and an annual rainfall somewhat greater than that of the Great Lake catchment. Numerous lakes on this area, some of considerable size, act as natural balancing reservoirs and, without artificial storage, render it possible to divert about 75 per cent. of the discharge of the Upper Ouse into the Great Lake through the Ouse Diversion Canal. Some further regulation of the Upper Ouse catchment by artificial storages is possible, but is not justified at the present time.

Immediately to the south of the James and Upper Ouse lies the catchment of the Little Pine River, having an area of 38 sq. miles. When required, Lake Kay can be converted into a regulating storage by constructing a dam across the Little Pine River immediately below the outlet of the lake. From this storage water can be diverted through a series of lagoons to the Ouse River, and thence by the Ouse Diversion Canal to the Great Lake. After allowing for losses by evaporation, the estimated continuous yield from the above mentioned catchments, when completely regulated by the Great Lake Dam, is 580 cusecs.

The Great Lake has a length of 13 miles, and is situated at an elevation above sea level of 3333 ft. at the sill of the outlet gates. At 4 ft. above sill level, corresponding to the original winter level, the area is 45 sq. miles, and at full supply level, that is 35 ft. above sill level, the area is 58 sq. miles, and the capacity is 1,150,000 acre-feet, which is sufficient to regulate the run-off from the areas tributary to the lake completely. The Great Lake has the fourth largest storage capacity in the world, as shown by the following table :—

	Storage Capacity. Acre Feet.
Elephant Butte	2,600,000
Assouan	1,865,000
Roosevelt	1,280,000
Great Lake	1,150,000

Its capacity exceeds that of the Burrinjuck Reservoir in New South Wales by nearly 50 per cent.

At a point about 5 miles west of the Great Lake the River Ouse flows through a deep rocky gorge known as Hell Gates. This point has been selected for diverting part of the flow into a flume by a low-concrete weir, the crest of which is at elevation 3,452·90 or 120 ft. above the lake. The flume carries the water for about half a mile to the mouth of the gorge, where it discharges through a concrete-lined stilling section into a canal. A view of the gorge and diversion head works is given in Fig. 4, below, while in Fig. 5, page 357, the flume itself is illustrated. In the distance in Fig. 4 can be seen the canal into which the flume discharges.

The flume, which is of reinforced concrete, is supported on a bench blasted out of the wall of the gorge and on dry stone walling across depressions. It is 9 ft. wide by 6 ft. deep, and is designed to carry 5 ft. depth of water. The grade is 1 in 330, and the capacity 450 cusecs. The walls are 4 in. thick at the top and 8 in. at the level of the floor, which is itself 9 in. thick. The walls and floor are reinforced both transversely and longitudinally by plain round bars, and a contraction joint, extending completely across walls and floor, is constructed at

Fig. 3. Scale { Horizontal. One Inch = 25,000 Ft. / Vertical: " " = 2,500 Ft.

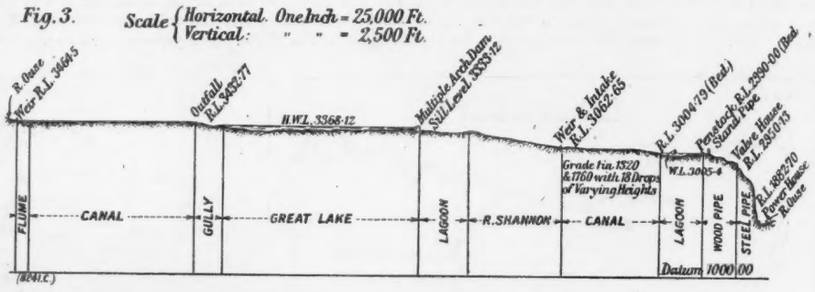


FIG. 4. OUSE DIVERSION HEADWORKS.

50-ft. intervals, a diaphragm of galvanised sheet iron rendering the joints tight. Coarse aggregate for concrete was obtained by crushing the hard diabase rock which forms the sides of the gorge, and fine aggregate was obtained by washing a mixture of clay and quartz sand excavated from the canal.

The foundation for the flume was trimmed to a true surface with a few inches of coarse concrete. Collapsible forms of hardwood made up in 4-ft. panels, could be rapidly erected in correct position on this floor. Speed in construction being essential, 400 lineal ft. of forms were employed, and construction was started from the upstream end, all materials being transported in trucks over the foundation. Concrete was mixed by a portable mixer at the downstream end of the forms and transported in barrows running inside the forms, which were specially designed for this purpose, as the precipitous nature of the country prevented the use of a roadway alongside the work. About 100 ft. of forms were re-erected and filled with concrete from each position of the mixer. Drains are

constructed through the foundation at intervals to discharge water from the side of the gorge.

For a length of 180 ft. at the up-stream end the flume has been built as a timber crib structure acting as a spillway. The river is of a very flashy nature and subject at times to considerable floods. At present, regulation of the canal is effected by hand, but it is proposed at a later date to replace the timber portion of the flume by a permanent concrete structure embodying automatic gates.

The canal, which has a total length of 5 miles 10 chains, carries the water to the watershed between the Ouse River and the Great Lake, and then discharges down a natural gully for a distance of 2 miles to reach the lake (see Fig. 2). The grade is 1 in 1,320 and the capacity 450 cusecs, at a velocity of 3¼ ft. per second. For the greater part of its length the cross-section is 24 ft. wide on the bottom, with slopes of 1¼ to 1, and a depth of water of 4·4 ft. An alternative cross-section, 15 ft. wide on the bottom with 1 to 1 slopes and 5·75 ft. depth of water, was adopted for a short distance to meet the requirements of steam shovel operation. In solid rock cuttings both types of cross-section are modified to give the equivalent area of waterway with vertical sides. The change from one type of cross-section to the other was effected by a gradual transition 2 chains in length.

The total quantity of material excavated was 230,000 cub. yards, of which 60,000 cub. yards was solid diabase rock, the greatest depth of cutting being 20 ft. Fig. 6 shows the canal at this spot. Of the remaining material a large portion was excavated by ploughs and scrapers, and the balance, which was unsuitable for scrapers, was removed by revolving steam shovels, and by ordinary pick and shovel work. Steam winches were successfully employed for hauling trucks on several portions of the work, while in other portions horses were more serviceable. A concrete weir at the outlet end of the canal prevents excessive draw down in the lower reaches, and movable screens are installed to prevent the passage of fish from the Great Lake to the River Ouse. Along the lower side of the canal, concrete spillways are constructed at intervals to discharge surplus water arising from excessive rainfalls in the area which is directly tributary to the canal itself.

(To be continued.)

FIG. 5. REINFORCED CONCRETE FLUME ON THE OUSE DIVERSION.

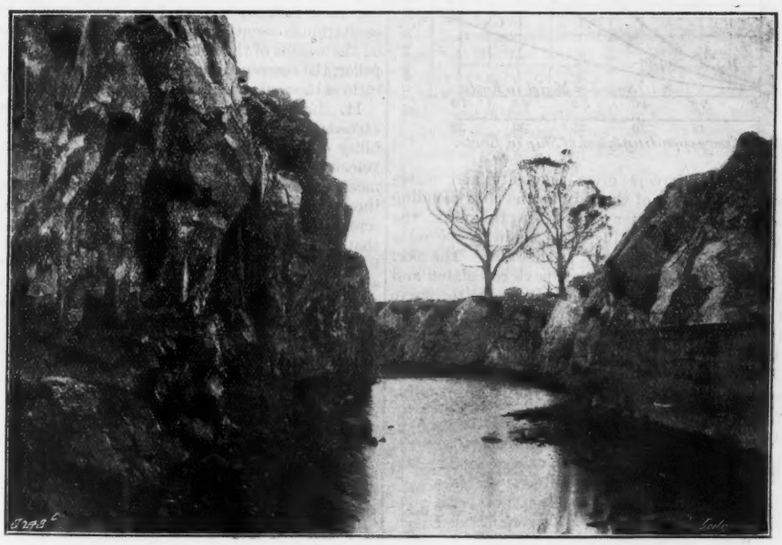


FIG. 6. ROCK-CUTTING ON THE OUSE DIVERSION.

AMERICAN TIN CONSUMPTION.—We read in *The Iron Age*, New York, that American consumption of tin in 1923 was close to 75,000 tons. In the last year of the war, 1918, it was 73,700 tons; in 1920, 69,500 tons; and in 1913, only 45,000 tons. Imports in 1923 reached 68,690, more than for any previous year.

THE PRINCIPLE OF DYNAMICAL SIMILARITY, WITH SPECIAL REFERENCE TO MODEL EXPERIMENTS.

By Professor A. H. GIBSON, D.Sc., M.Inst.C.E.

(Continued from page 327.)

(7) *Resistance of Wholly Submerged Bodies.*—When a body is submerged in a current to such a depth that no surface waves are formed, gravity has no effect on the resistance. This is the case with a deeply-submerged submarine or with an airship. If the speed is uniform, and if the effect of compressibility may be neglected, the resistance may evidently depend upon the relative velocity of fluid and body; the density and viscosity of the fluid, and the size and shape of the body. In a series of geometrically similar bodies each is defined by a single linear dimension l, and the resistance R will be given by the relationship

$$F(R, l, v, \rho, \mu) = 0.$$

As already indicated (equation 4), this leads to the result

$$R = \rho l^2 v^2 \phi\left(\frac{lv}{\nu}\right).$$

If experiment shows that the resistance is proportional to v^n, this shows that $\phi\left(\frac{lv}{\nu}\right)$ must equal $\left(\frac{lv}{\nu}\right)^{n-2}$, so that

$$R = \frac{\rho l^n v^n}{\nu^{n-2}}$$

If the resistance is proportional to v^2, the term involving ν becomes unity, indicating that viscosity no longer has any direct effect on the resistance.

The value of the function ϕ might be found by plotting observed values of $\frac{R}{\rho l^2 v^2}$ against simultaneous values of $\frac{lv}{\nu}$ and by finding an empirical equation to represent the curve joining the plotted points. It should be noted that since the values of both terms in the expression are dependent on v, the form of the function can be determined from experiments on a single body at different velocities in any one fluid, and that this enables the value of the resistance in any other fluid to be calculated.

In model experiments, if the medium is the same for model and original and if the speeds be chosen so that $v_m = \frac{vl}{l_m}$, where the suffix m denotes the model, we shall have

$$\frac{lv}{\nu} = \frac{l_m v_m}{\nu}$$

so that $\phi\left(\frac{lv}{\nu}\right)$ becomes a constant and

$$\frac{R}{R_m} = \frac{l^2 v^2}{l_m^2 v_m^2} = 1$$

At these "corresponding speeds" the resistance of the model and of the original are equal.

Unfortunately, this relationship would require such high speeds for the model as to be of no practical value. If, however, the model experiments can be carried out in a medium whose kinematic viscosity is less than that of the original, its corresponding speeds are reduced. If, for example, the resistance of an airship model is to be investigated, the model tests may be carried out in water whose ν at ordinary temperatures has a value of about 1/13 that of air.

Here

$$\frac{v_m}{v} = \frac{1}{13}\frac{l}{l_m}$$

and the resistance of the original at the speed v is given by

$$\frac{R}{R_m} = \frac{\rho}{\rho_m}\left(\frac{lv}{l_m v_m}\right)^2 = 169\,\frac{\rho}{\rho_m}$$

Alternatively, compressed air may be used as the medium in an air tunnel. Such a tunnel is in operation at Langley Field (U.S.A.) in which air, at pressures up to 20 atmospheres may be used. Adopting this pressure and neglecting the small change in viscosity with pressure, we have

$$l\rho v = l_m \rho_m v_m$$

or

$$\frac{v_m}{v} = \frac{l\rho}{l_m \rho_m} = \frac{1}{20}\frac{l}{l_m}$$

Thus with a 1/20 scale model, identical speeds for

model and original are "corresponding speeds," and at these speeds

$$\frac{R_m}{R} = \frac{\rho_m l_m^2 v_m^2}{\rho l^2 v^2} = \frac{1}{20}.$$

Where a high degree of accuracy is not essential advantage may be taken of the fact that the resistance of an airship body is approximately proportional to the square of the velocity. In this case, since

$$R = \rho l^2 v^2$$

it is immaterial at what speed the model experiments are carried out, so long as this is above the "critical speed."

This discussion applies equally well to any case of steady motion of a totally-immersed body in a medium whose compressibility under the condition of test may be neglected. Thus a similar relationship would be obtained for the pressures on two similar plane surfaces, or for the lift and drift forces on an aeroplane in steady flight. A direct comparison by Eiffel between the results of experiments made on a model and a full-sized aeroplane in flight shows that these agree on the average within 1 per cent.*

(8) *Resistance of Partially-submerged Bodies.*—When a body is partially submerged, or, although submerged, is so near the surface that surface waves are produced, part of the resistance to motion is due to this wave formation. Since the form of the waves is governed by gravity, the influence of this factor must now be taken into account, and we have the relationship

$$F(R, l, v, \rho, \mu, g) = 0$$

Since there are now six quantities involved, the general equation will contain three terms, and, proceeding as before, it appears that this becomes

$$\psi\left(\frac{R}{l^2 v^2 \rho}\right)\left(\frac{\nu}{l v}\right)\left(\frac{g l}{v^2}\right) = 1 \quad . \quad (13)$$

or

$$R = l^2 v^2 \rho \phi\left(\frac{\nu}{l v}\right)\left(\frac{g l}{v^2}\right) \quad . \quad . \quad (14)$$

For dynamical similarity it is necessary that each of the terms of ϕ shall have the same value for model and original. But if, as is usual in practice, both are to operate in water, ν is sensibly constant, while g is also constant, so that for exact similarity both $l v$ and l/v^2 must be constant. In other words neither v nor l can vary. It follows that the lines of flow and the wave formation around a ship and its model in the same liquid cannot simultaneously be made similar.

If the model could be tested in a fluid such that $\frac{\nu_m}{\nu} = \left(\frac{l_m}{l}\right)^{\frac{3}{2}}$, the necessary conditions would be satisfied with corresponding speeds proportional to the square roots of corresponding linear dimensions. Since no suitable fluid is available, it remains to be seen whether any of the factors involved in the function ϕ may reasonably be neglected so as to give an approximation which is likely to be of use in practice.

Experiment shows that the resistance of a ship-shaped body at the speeds usual in practice is proportional to v^n, where n is approximately 1·83, and the nearness of this index to 2·0 indicates that the direct effect of viscosity is small. If it be assumed that this influence of viscosity is negligible,† the argument $\frac{\nu}{l v}$ may be omitted from the equation, which then becomes

$$R = l^2 v^2 \rho \phi\left(\frac{g l}{v^2}\right) \quad . \quad . \quad (15)$$

If now $\frac{l}{v^2}$ be made the same both for the model and the original,

$$\frac{R}{R_m} = \frac{\rho}{\rho_m} \cdot \frac{l^2}{l_m^2} \cdot \frac{l}{l_m} = \frac{\rho}{\rho_m}\left(\frac{l}{l_m}\right)^3 = \frac{\rho}{\rho_m} \cdot \frac{D}{D_m} \quad (15A)$$

where D is the displacement.

In this case the "corresponding speeds" at which wave and eddy formation are the same for ship and model, are given by

$$\frac{v}{v_m} = \sqrt{\frac{l}{l_m}}$$

9. *Model Experiments on the Resistance of Ships.*—In practice these corresponding speeds are used, but allowance is made for the different effects of viscous resistance in the ship and the model, by the "Froude" method.

In determining the resistance of any proposed ship, a scale model is made, usually of paraffin wax, and is towed through still water, the resistance corresponding to a number of speeds being measured by dynamometer. A curve A A, Fig. 2, is plotted showing resistance against speed.

The length and area of the wetted surface being known, the skin friction ($f_m A_m v_m^n$) is calculated, the coefficient being taken from Froude's results on the resistance of flat planes towed endwise. The curve B B of frictional resistance can now be drawn, and the intercept between A A and B B gives the eddy and wave-making resistance of the model. If now the horizontal scale be increased in the ratio $\sqrt{S}$: 1, where S is the scale ratio of ship and model, and if the vertical scale be increased in the ratio

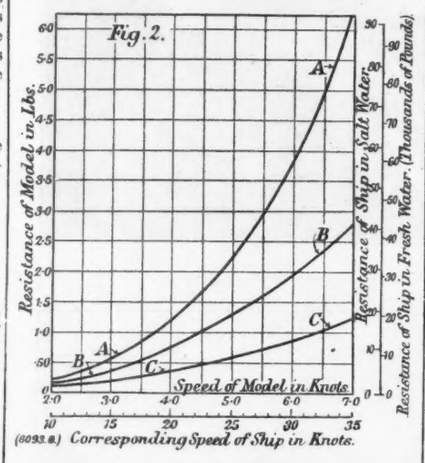


Fig. 2.
Resistance of Model in Lbs.
Resistance of Ship in Salt Water
Resistance of Ship in Fresh Water (Thousands of Pounds)
Speed of Model in Knots
A
B
C
(6093.a) Corresponding Speed of Ship in Knots.

D : 1, this intercept gives the eddy and wave-making resistance of the ship at the corresponding speed. If fresh water is used in the tank, the vertical scale is to be increased again in the ratio of the densities of salt and fresh water. The skin friction (f A v^n) of the ship is next calculated and set down as an ordinate from B B to give the curve C C. The intercept between the curves A A and C C now gives, on the large scales, the total resistance of the ship.

The resistance at any speed v, may be calculated from model observations at the corresponding speed v_m, as follows :—

Total resistance of model (observed)	= R_m . lbs.
Skin friction of model (calculated) ...	= $f_m A_m v_m^n$. lbs.
∴ Wave + eddy resistance of model ...	= $R_m - f_m A_m v_m^n$ = F lbs.
Wave + eddy resistance of ship in salt water	= D F × $\frac{64}{62 \cdot 4}$. lbs.
Total resistance of ship	= $\frac{64}{62 \cdot 4}$ D F + f A v^n . lbs.

10. *Screw Propellers.*—The thrust T of a screw propeller of given shape may be assumed to depend upon its diameter; speed of revolution n; speed of advance v; the physical properties of the fluid; and, if the depth of immersion is not sufficiently great to prevent surface disturbance, also on the weight of the medium, *i.e.*, on g. In this case, with similar propellers immersed to depths proportional to their diameters,

$$F(T, l, v, \rho, \mu, n, g) = 0.$$

Here n is of dimensions t^{-1}, and proceeding in the usual way we get

$$T = \rho l^2 v^2 \phi\left(\frac{l n}{v}\right)\left(\frac{\nu}{l v}\right)\left(\frac{l g}{v^2}\right) \quad . \quad . \quad (16)$$

while the efficiency

$$\eta = \psi\left(\frac{l n}{v}\right)\left(\frac{\nu}{l v}\right)\left(\frac{l g}{v^2}\right) \quad . \quad . \quad (17)$$

By adjusting the speed of rotation so that the ratio of the peripheral speed to the speed of advance is constant, the first factor $\frac{l n}{v}$ becomes constant. Since the propellers are similar this means that the slip ratios must be the same. When this condition is satisfied, equation 16 becomes

$$T = \rho l^2 v^2 \phi\left(\frac{\nu}{l v}\right)\left(\frac{l g}{v^2}\right) \quad . \quad . \quad (18)$$

This is the same form of equation as was deduced for the resistance of partially submerged bodies, and, as in that case, it is only where the influence of viscosity is negligibly small that dynamic similarity can be attained. If the influence of viscosity be neglected, we have, in the same fluid

$$\frac{T}{T_m} = \left(\frac{l}{l_m}\right)^3$$

if the screw and its model be run at the corresponding speeds

$$\frac{v}{v_m} = \sqrt{\frac{l}{l_m}}$$

If the depths of immersion be so great that no surface waves are formed gravity ceases to affect the results, and if at the same time the influence of viscosity be neglected, the equation becomes

$$T = K \rho l^2 v^2,$$

and it is immaterial at what speed the model experiments are carried out.

Such experiments as are available show that in the case of screw propellers working in water the results of such model experiments are in close agreement with those on full-sized propellers. This might be expected since the velocities are usually so high that the motion of the water in the vicinity of the blades is highly turbulent, in which case viscosity will play a very small part in the phenomenon.

If "cavitation" takes place the foregoing reasoning may still be expected to hold good. Since cavitation is essentially a pressure effect and depends on the weight of the column of water above the propeller, the corresponding speeds must now be in the ratio of the square roots of corresponding dimensions.

11. *Air Screws.*—If in an air screw the tip velocity exceeds about 600 f.s., the effect of the compressibility of the air begins to be marked, while as the velocity approaches that of sound waves in the medium the effect becomes all important. Owing to the nature of the construction, moreover, an air screw is very liable to distort under its loading, so that the density and elasticity of its material are involved in any complete relationship involving similarity. Since the thrust on a blade depends on the density of the air, while the centrifugal force depends on the weight of the material, the forces and moments due to these two causes can be simply related only if ρ/ρ^1 is constant, where ρ^1 is the density of the material.

The general relationship then becomes

$$F(T, l, v, \rho, \rho^1, \mu, n, V_p, E) = 0$$

from which we get,

$$T = \rho l^2 v^2 \phi\left(\frac{l n}{v}\right)\left(\frac{\nu}{l v}\right)\left(\frac{v}{V_p}\right)\left(\frac{\rho}{\rho^1}\right)\left(\frac{E}{\rho v^2}\right) \quad . \quad (19)$$

Since V_p is constant for a given fluid under given conditions, it follows that for the term v/V_p to be identical for the model and the original v must be the same for both. If of the same material, $E/\rho v^2$ and ρ/ρ^1 will then be the same for both. But this condition inserted in the second term necessitates l being the same for both, so that true dynamic similarity cannot be obtained with a scale model working in the same medium. If, however, the influence of viscosity be neglected, the required conditions are satisfied by running model and original at the same tip speeds, and at the same translational velocities. Although this means somewhat high rotational speeds they are not higher than can readily be attained in model experiments.

Experiments indicate that the outstanding correction due to the influence of viscosity is very small. Thus experiments by Eiffel* on a propeller

* Adv. Com. for Aeronautics. T.R. 1911–12, page 295.

† This does not involve the assumption that skin friction is unimportant or that viscosity plays no part in the phenomenon. It is in effect assuming that skin friction, instead of being proportional to v^n, where n is slightly less than 2, is proportional to v^2. In this case the resistance is due to the steady rate of formation of eddies at the surface of the body, and once these have been formed and have left the immediate vicinity of the body, the rate at which they are damped out by viscosity has no effect on the drag.

* Adv. Committee for Aeronautics. T.R. 1911–12, page 36. See also T.R. 1911–12, page 167.

model, compared with others on a similar propeller three times the diameter at the same tip speeds showed that the thrust predicted from the model tests was on the average 2·5 per cent. less than the measured thrust, while the two efficiencies were sensibly identical.

Similar tests at the National Physical Laboratory on two air screws having a scale ratio of 7·5 to 1, and run at very different tip speeds, indicate that if the effect of compressibility and viscosity be entirely neglected, in which case

$$T = k \rho l^2 v^2$$

closely approximate results are obtained. In this case the predicted thrust was only 4 per cent. less than the measured thrust and the efficiency 3 per cent. lower.*

12. *Scale Effects—Resistance of Plane Surfaces.*†—From what has already been said, it will be evident that in most model experiments some one of the factors involved tends to prevent exact similarity, and introduces some scale effect.

The resistance of square plates exposed normally to a current affords a typical example of scale effects. Expressing the resistance of such plates as

$R = k^1 \rho v^2$ in absolute units (British or C.G.S.)
$= k v^2$ where k is in lb. wt. per sq. ft. and v is in feet per second.

experiments show the following values of k^1 and of k.

	k^1	k	Size of Plate.
Dines*	0·56	0·00136	1 ft. square.
Canovetti† ..	0·56	0·00134	3 ft. diameter (circular).
Eiffel‡	0·55	0·00133	10 in. square.
Eiffel‡	0·56	0·00136	14 in. square.
Eiffel‡	0·59	0·00142	20 in. square.
Eiffel‡	0·61	0·00147	27 in. square.
Eiffel‡	0·62	0·00150	39 in. square.
Stanton§ ..	0·52	0·00126	2 in. square.
Stanton§ ..	0·62	0·00148	5 ft. square.
Stanton§ ..	0·62	0·00149	10 ft. square.

* Proc. Roy. Soc., vol. xlviii, page 252.
† Société d'Encouragement pour l'Industrie Nationale, Bulletin 1903, vol. i, page 189.
‡ Eiffel, "Résistance de l'Air."
§ Collected Researches, N.P.L., vol. i, page 261.

Such experiments show that while $\frac{R}{l^2 v^2 \rho}$ is almost independent of v, it increases by about 18 per cent. as the size of the plate is increased from 2 in. to 5 ft. square.

It is impossible to say without further examination that this effect is not due to compressibility. Indeed if compressibility has any influence on R, a dimensional effect can occur which may be in accordance with a v^2 law of resistance, for the general expression

$$R = \rho l^2 v^2 \phi \left(\frac{l v}{\nu}, \frac{v}{V_p}\right) \quad . \quad . \quad (20)$$

may be written

$$R = \rho l^2 v^2 \phi \left(\frac{l V_p}{\nu}, \frac{v}{V_p}\right)$$

and since by hypothesis R is proportional to v^2, this becomes

$$R = \rho l^2 v^2 \phi \left(\frac{l V_p}{\nu}\right) \quad . \quad . \quad . \quad (21)$$

An investigation of the possible effect of compressibility shows that this is less than 1 per cent. at speeds up to 100 miles per hour, so that an explanation of the observed dimensional effect based on this factor is not admissible.

It has been suggested that,‡ since, as shown by Mr. Hunsaker's observations on circular discs, there is a critical range of speed determined by the form of the edge, and not dependent on the size of plate, the apparent discrepancy between R/v^2 = constant and R/l^2 = variable, may be due to the results of various observers having been affected by such critical phenomena, which were not, however, sufficiently marked to attract attention. To determine whether this explanation is valid would require an experimental investigation of the forms of edge which have been used.

The more probable explanation would appear to be that while experiments on any one plate have usually been taken as showing the resistance to be proportional to v^2, this is only approximately true.

An examination by Messrs. Bairstow and Booth* of all reliable experiments on square plates leads to the conclusion that an empirical formula of the type

$$R = a (v l)^2 + b (v l)^3$$

gives a close approximation to the experimental results. For values of $v l$ ranging from 1 to 350, a and b have the values 0·00126 and 0·0000007, respectively. Here v is in feet per second, and R in lbs.

Neglecting compressibility, this indicates that $\phi \left(\frac{l v}{\nu}\right)$ equals $m + n v l$, where m and n are constants for any particular fluid under given pressure and temperature conditions.

It may be noted that experiments by Stanton† show that the pressures on the windward side of a square plate are not subject to a dimensional effect, but that the whole variation can be traced to changes in the negative pressure behind the plate.

(To be continued.)

* Adv. Committee for Aeronautics. T.R., 1911–12, page 36.
See also T.R., 1911–12, page 167.
† "Mechanical Properties of Fluids," Blackie and Son, Glasgow, 1923, chapter v.
‡ By Mr. E. Buckingham, "Smithsonian Miscellaneous Collections," vol. lxii, No. 4, January, 1916.

* Technical Report, Advisory Committee for Aeronautics, 1910–11, page 21.
† Proc. Inst. C.E., vol. clxxi; also "Collected Researches of the National Physical Laboratory," vol. v, page 192.

THE INSTITUTE OF METALS.

(*Concluded from page* 346.)

On the members re-assembling on Thursday morning, the 13th inst., the secretary announced that the "May Lecture" would be held at the Institution of Mechanical Engineers on June 4. The Institute formed part of the Empire Mining and Metallurgical Congress to be held from June 3 to 6, and it was hoped that members of the Institute would also become members of the Congress. The Autumn meeting would take place in London, the dates provisionally fixed being from September 8 to 11, on which occasion there would be visits to the British Empire Exhibition and excursions in the neighbourhood of London.

Copper-Zinc Alloys.

The first paper taken at Thursday morning's meeting was by Mr. Kei Iokibe, on "The Copper-Zinc Alloys which expand on Solidification." It was read in abstract by Professor Turner. The paper stated that the remarkable expansion which took place when certain copper-zinc alloys were slowly cooled, first observed by Turner and Murray, had been re-examined. Extensometer tests showed that the expansion was observed only with alloys containing from 5 per cent. to 30 per cent. of copper. There was a sharp maximum peak with 15 per cent. of copper. The alloys, if very quickly cooled from the molten state had a density which was slightly higher than that calculated on the assumption of no volume change; in other words there was a contraction on alloying. The amount of expansion varied with the rate of cooling; with very slow cooling the density might fall from 7·3 to 6·2, corresponding with an expansion of about 18 per cent. The force of the expansion was sufficient to break the crucibles in which the alloys were allowed to solidify. The increase of bulk was due to the formation of minute voids, which were not gas holes. When compressed, the alloys increased in density; drillings or turnings gave values practically identical with those obtained by very rapid cooling. Slowly cooled alloys were of uniform composition throughout; but chill cast bars though of uniform average composition when examined in horizontal sections, were inversely segregated vertically. Rapid cooling led to a concentration of copper, the less fusible metals being towards the centre of the bar. The more rapid the cooling, the greater was the difference in copper content between successive vertical layers on proceeding from the outside to the inside of the bar. The difference might amount to as much as 25 per cent. of the total copper content. The maximum inverse segregation in rapidly cooled alloys coincided with the maximum expansion of slowly cooled alloys. Chill cast alloys on annealing expanded, while the copper content tended to become uniform throughout. In the range of considerable expansion and of inverse segregation, there was no definite microstructure; separate constituents were no longer clearly recognisable. The expansion appeared to be connected with the change, on slow cooling or annealing, from the unstable state of inverse segregation to the stable state of uniform composition.

Dr. Rosenhain thanked Professor Turner for having presented the paper, which he had revised after the author had left England for Japan.

Dr. S. W. Smith enlarged the remarks made by the author; he found that the connection between the changes in volume and the variation in composition from the outside to the centre were not very obvious, the long solidification interval coming into play. There was no doubt of the volume change at the end of the copper-zinc series dealt with by the author, and the latter had clearly shown that this volume change was accounted for by void spaces in the metal. He accepted the author's statements with reference to the volume change. He (the speaker) did not like the author's term "inverse segregation"; this was generally referred to as "liquation," which was not, perhaps, a satisfactory term either. The word "inverse" implied a somewhat unexpected occurrence, but the phenomenon had long been known. It was associated with the solidification interval and the steep temperature gradient from the outside to the interior, and the two gave rise to liquation in the alloys.

Dr. O. F. Hudson said one point was rather confusing, and it concerned the meaning of the word "expansion"; the author meant expansion as a whole as apart from density. The expansion noted was due to void spaces, giving unsoundness, and this was an important feature to bear in mind from the practical point of view.

Professor C. H. Desch suggested that the changes were due to crystal thrust by growing. There was no evidence of change of density, but evidence of change of volume. He showed how a crystal by growing in a super-saturated solution was able to lift a weight placed directly upon it. In the group of alloys dealt with by the author a crystal thrust also occurred leading to a larger apparent volume, but the real volume was smaller.

Corrosion of Zinc and Lead.

The second paper had reference to "The Relative Corrosion of Zinc and Lead in Solutions of Inorganic Salts," by Dr. J. Newton Friend and Mr. J. J. Tidmus. It was read in abstract by the former. It gave the rates of corrosion of both these metals in varying concentrations of different inorganic salt solutions, sodium chloride, potassium chloride, potassium sulphate, sodium sulphate and potassium nitrate. The results were found closely to resemble those obtained with iron in similar conditions, and the explanation for the three categories of metals appeared to be substantially the same.

Mr. U. R. Evans did not quite agree with the authors in their suggestion that iron hydroxide was an oxygen carrier. Chromates not only stopped the corrosion of iron but also that of other metals, in that they formed a protective film; this was said in reference to a statement by the authors to the effect that pure electrolytic iron had been kept in dilute potassium bichromate solutions for over ten years without the slightest solvent action being apparent. (Mr. Evans here showed on the black-board several mathematical formulæ indicating the rate and velocity of oxygen diffusion through the water on the metal, and variables giving the electrical and chemical actions.)

Dr. G. D. Bengough found the paper of interest, particularly since the authors concluded that the experimental results he obtained were satisfactorily explained on a colloidal view of corrosion. A difficulty in the matter of any electro-chemical view of corrosion was the shape of the numerous curves connecting corrosion with salt concentrations, and the existence of a "critical concentration" which did not occur at the same salt concentration as the maximum "oxygen solubility." It seemed easier to account for the curves in the paper, on a colloidal hypothesis. But the work of Adeney and his colleagues on the rate of oxygen absorption by salt solutions had introduced a new and very important factor in the case. The author's maximum corrosion points occurred close to the position which would be expected on an electro-

chemical hypothesis of Adeney's data being taken into account; these data in fact destroyed the colloidal hypothesis in explaining the shapes of many of the curves. The authors discussed very briefly the action of corrosion products in connection with the behaviour of zinc in a KNO_3 solution. He (the speaker) wished they had gone more deeply into this, for this was the branch of corrosion work which was most in need of further details. So far, his (the speaker's) experience had confirmed the view in the Sixth Report, that pits often occurred owing to the local breakdown of scale. In chloride solutions, zinc became coated with a layer of hydroxide oxycarbonate and oxychloride in various proportions, depending on the conditions of the experiments, and the layer might locally lower the rate of corrosion very noticeably. He (the speaker) drew attention to the fact that the nitrate curve differed notably from that of the chloride; it was wholly below the value for distilled water. Nitrate ions had no striking power of precipitating positive colloids, but were powerful anodic polarisers in some cases. Here again an electro-chemical hypothesis seemed to cover the facts best. In the case of iron and lead there seemed to be a fair agreement with the colloid hypothesis. Nitrates appeared greatly to stimulate lead corrosion as compared with distilled water; it was at any rate clear that anodic polarisation was not an important factor; if it occurred it was very temporary. In the case of iron there should be taken into account the hydrolysis of ferric nitrate, and the fact that in the absence of traces of chloride, iron could show strong anodic polarisation in nitrate solutions. Summing up the data in the paper he (the speaker) found there was not much, if any, support for the view that the primary, and the most important secondary, action of corrosion was essentially colloidal. The initial action appeared to be electro-chemical in many electrolytes. He added that he had considerably changed his views because of Adeney's experiments, the effects of nitrates on corrosion, the experiments by Dr. Friend with high speed water on iron, the importance of differential aeration, the work of Osaka, and the possibility of scale functioning as a cathode owing to passage of electrons from the metal.

Mr. W. H. J. Vernon said the authors outlined four factors by which the corrosion of a metal might be influenced when placed in a solution of a salt. The last of these dealt with the influence of the anion in precipitating colloid on the metal surface and so reducing the rate of corrosion. Another factor, however, might well have been added, namely the influence of the anion in reducing electro-chemical action through anodic polarisation. It had been suggested in the discussion that the effects attributed by the authors to colloid precipitation were in reality due to anodic polarisation. Having regard to the extent to which each explanation met the recorded facts, he thought one should hesitate considerably before rejecting unconditionally the one advanced by the authors. In the paper the influence of a number of salts were dealt with, but he need only refer to the chloride and the nitrate. If these salts functioned in the capacity of colloid precipitants there should clearly be little to choose in their respective behaviour, since this capacity was determined largely by the valency of the anion. On the other hand if anodic polarisation were the determining factor there should be a very pronounced difference in the behaviour of the two salts, owing to known differences in the polarising properties of the respective anions. It was noteworthy that in the author's zinc experiments the disposition of the curves was such as would be expected if the salts functioned in virtue of their anodic effect, whilst in the case of lead the authors stated that chlorides and nitrates behaved as one would expect if their function were that of colloid precipitants. It should be noted that the zinc used in the experiments was very impure, whilst the lead was of a relatively high degree of purity. That might be a coincidence, but to him (the speaker) it appeared very significant. He was led to suggest that the two actions referred to were not mutually exclusive, but rather, superimposed. Thus, where little opportunity presented itself for primary electro-chemical action, the effect of colloid precipitation might predominate over that of polarisation; on the other hand, where conditions were favourable for electro-chemical action, then the relative polarising effect should be the predominating factor.

In the course of his reply Dr. Friend found the suggestions made by the two last speakers to be quite fair, since corrosion was very complex and very many actions could take place simultaneously. With regard to the present explanation for the rise in the curve not being preferential to colloidal action, he (Dr. Friend) said it never was, and showed that Adeney, in his experiments, had not carried his own curve beyond a point, using only sodium chloride. Up to that point there was agreement between Adeney and him (Dr. Friend), but Adeney's work had been restricted down to that point and was carried no further. Zinc was very susceptible to nitric acid and to the action of nitrates. Mr. Evans said that iron hydroxide was not an oxygen carrier; but it really was according to his (Mr. Evans') own showing, following the data he had given on the blackboard. Mr. Evans' mathematical formulæ were perfectly sound, but he (Dr. Friend) used a much more simple formula which completely covered the case.

X-RAY STUDIES.

The third paper taken on Thursday morning was contributed by Messrs. E. R. Jette, G. Phragmen and A. F. Westgren, of Stockholm, and was entitled "X-ray Studies on Copper-Aluminium Alloys." It was read in abstract by the secretary. The alloys for the investigation were made by melting together copper and aluminium of the usual electrolytic quality. Sand crucibles and a carbon resistance furnace were used for this purpose. To lower the oxidation the meltings were in some cases protected by a layer of soda-glass slag. All the alloys were examined microscopically, to be certain that they were practically homogeneous and free from inclusions. The copper content was determined in all the alloys, and, whenever especially important, the aluminium content was also established. A series of these alloys, slowly cooled from the liquid state, was investigated by the powder method. The X-ray apparatus (iron anticathode) and the cameras used for taking the powder photograms were described at a recent meeting of the Iron and Steel Institute.* Photographs were reproduced in the paper, from which it could be seen that four different phases appeared in these alloys. The $CuAl_2$ phase had tetragonal structure, with an axial ratio of 0·805. The elementary prism was body-centred, and contained four molecules of $CuAl_2$. The phase present in the range 16 to 25 per cent. aluminium had a cubic lattice. In the 16 per cent. alloy the elementary cube contained about 52 atoms, and in the 25 per cent. alloy the corresponding number was only 49. The solutions within the range were thus formed by a "complex substitution." The curve of the change of density was in closest agreement with the one obtained by supposing that three copper atoms in the lattice were replaced by two aluminium atoms. A photograph of a quenched specimen containing 12·5 per cent. aluminium showed lines corresponding to a phase stable only at higher temperatures.

Dr. H. Weiss, of Paris, said that Bain and his school in America had done some pioneer work on the subject about a year ago, but their studies were not satisfactory from the point of view of the metallurgist, owing to lack of particulars on the preparation of the alloy samples, and also because some of the results were contradictory, compared with the best established results of thermal and microscopical analysis. For this reason, he (the speaker) was able to state a few months ago before the Physical Society that the work done by Dr. Owen and Mr. Preston in connection with Dr. Rosenhain, at the National Physical Laboratory, was the first work to give satisfaction to the metallurgist. The first paper by Owen and Preston was on the copper-aluminium system, like the paper then before the meeting, and both papers agreed together. In the ranges of concentration the law found at the National Physical Laboratory could be considered completely verified, to the effect that one atom of aluminium replaced one atom of copper in the lattice of pure copper, and that one atom of copper replaced one atom of aluminium in the lattice of pure aluminium. Concerning the structure of the $CuAl_2$ phase, Owen and Preston had found a cell corresponding to a diagram drawn on the blackboard, which the speaker compared with Westgren's cell. The results agreed together regarding the size of the cell and the number of molecules per cell. There was a difference in that Westgren claimed that some of the molecules were in a different position so as to maintain a body centred symmetry. The Owen and Preston structure was the coupling of two body-centred lattices. The difference was a question of distribution of the molecules inside the cell. Westgren's conclusions were rather vague; those by Owen and Preston were bolder. Westgren did not seem to obtain all the results he ought to. In the observation of the spectra, Owen used an ionisation chamber; Westgren used a photographic method, and in his (the speaker's) opinion the photographic method was preferable, being more sensitive, and if the reflections were poor it was always possible to make a longer exposure. Westgren found all the lines found by Owen and Preston, and a few more, this being due to the photographic method adopted. The method of studying alloys by X-rays was generally called the powder-method. The alloys reduced to grains as fine as possible were placed in the X-ray beam, and a spectrum of diffracted rays was observed. This method met the case if the sample was a simple lattice; as, for example, a cubic lattice having strong reflections, and if one had simply to settle between a face-centred or a body-centred cubic lattice. This had been the case for nearly all the metals studied by Hull. If the lattice was of lesser symmetry, the problem was practically indeterminate, unless one had a previous knowledge of the nature and symmetry of the lattice. And since the sensitiveness of the method for observing the spectrum was limited, one generally missed a few lines, and this might upset the character of the inference. For this reason, X-ray examiners always tried to get single crystals from which the results were much more precise and better seen. In conclusion, the speaker said that the powder-method could give a solution only in very simple and exceptional cases. Single crystals had to be used to get a sound result. For qualitative information, when a constituent was too small to be identified under the microscope, or for data on the size or orientation of the crystals, the powder-method was a valuable one. No results which it cannot yield should be demanded of it.

Dr. Owen congratulated the authors for the very clear photographs they had obtained, since the making of clear photographs was surrounded with many difficulties. He had found at the copper end a distinct increase in the size of the lattice; his figures for aluminium were almost identical with those of the authors, and at the other end he could not find any increase in the size of the lattice. In regard to the $CuAl_2$ the part of the structure he assigned to it fell in with the lines of the authors, except about three. Here Dr. Owen exhibited a slide of his structure showing the atoms at the edges, to differentiate it from the authors' photograph of a $CuAl_2$ crystal rotating around the tetragonal axis. One point he (the speaker) emphasised was that the observed planes corresponded with the calculated. His density agreed with that of the authors. The γ on the authors' diagram he had not examined at all, but in other parts he could reproduce the structure very accurately.

Dr. Rosenhain stated that the X-ray examination of alloys gave an insight into them which was not possible to arrive at by other methods; it made it possible to combine accurate physical manipulation with correct metallurgical preparation. At one part of their paper the authors had found that the solid solutions were formed by a "complex substitution"; the curve of the change of density was in closest agreement with that obtained by supposing three copper atoms replaced by two aluminium atoms. How the unusual form of substitution could be brought into accordance with the cubic symmetry of the atomic arrangement, the authors frankly added, was still an unsolved question. This implied a destruction of symmetry, but Dr. Rosenhain said there was no such destruction of symmetry; the alloys were not homogeneous. When more

* See ENGINEERING, vol. cxi, page 278.

complete examinations were made many difficulties would be found to have disappeared.

Professor F. C. Thompson referred to the paper read on the preceding afternoon showing change of symmetry by mechanical deformation (see page 344 *ante*) and lattices would show the same sort of occurrence, a change from the cubic-centred into the face-centred type. The powder-method with brittle material might be satisfactory, but with ductile material it was open to serious objections.

Physical Properties of Zinc-Bronze.

The fourth paper taken on Thursday morning dealt with "The Effect of Casting Temperature on the Physical Properties of a Sand-cast Zinc-Bronze," by Mr. F. W. Rowe. We reproduce this on page 384 of the present issue.

Mr. G. L. Bayley stated that he had carried out similar work and his results generally bore out the author's. His (the speaker's) castings were made in dry sand. Where unsoundness occurred this was very fine and could not be ascertained by examination with a lense, only by microscopic examination. With a lower casting temperature he found the density to increase, and another effect of a comparatively low casting temperature was an eutectoid lower in amount. The author's results would afford a good guide to foundrymen.

Alloys of Copper and Cadmium.

The first paper taken at the meeting of Thursday afternoon was on "The Constitution of the Alloys of Copper and Cadmium," by Mr. C. H. M. Jenkins and Dr. D. Hanson. It was read in abstract by the former. It stated that the alloys of copper and cadmium had been previously investigated by Sahmen, revealing the presence of the two compounds Cu_2Cd and Cu_2Cd_3. According to the authors' redetermination of the constitution of this system of alloys there were six primary constituents α β γ δ ϵ and η capable of separating from the liquid condition. Two eutectics were found to occur. Under ordinary conditions of cooling from the liquid state of certain of the alloys, the metastable eutectic between β and δ was found to occur in the place of the stable eutectic between γ and δ. Subsequent annealing of these alloys containing the metastable β and δ eutectic resulted in the formation of the stable γ phase. The constitution of the alloys in the solid state had been determined to 300 deg. C. for the copper-rich alloys, and to 200 deg. C. for cadmium-rich alloys. The solid solubility of cadmium in copper (α) had been found to be approximately 2·7 per cent., while the solubility of copper in cadmium was approximately 0·07 per cent. The concentrations representing the homogeneous phase fields were suggested to correspond closely to those of the compounds Cu_2Cd, Cu_4Cd_3, Cu_2Cd_3 and $CuCd_3$. At temperatures below that of their formation Cu_4Cd_3, Cu_2Cd_3 and possibly $CuCd_3$ possessed a solubility in the solid state for either copper or cadmium.

Mr. A. J. Murphy said that from the point of view of the constitutional diagram one of the most striking facts about the system as now established was the difficulty of causing the reaction β + liquidus $\rightarrow$ γ to occur. He would like to ask whether the authors had formed any opinion as to why this reaction was so easily suppressed. It was interesting to note that the compound corresponding to the gamma solid solution Cu_4Cd_3 contained more atoms in the molecule than any of the other three compounds corresponding to the β, δ and ϵ solid solutions. This might suggest that the facility with which the β + liquidus $\rightarrow$ γ reaction was suppressed might be connected with the relative complexity of the molecule of Cu_4Cd_3 which had to be formed. But it seemed more probable that the cause was in the nature of the solid β phase which, for some reason, did not react readily with the liquidus with which it was in contact. Here Mr. Murphy referred to the zinc-antimony system, a similar one, in which a compound Zn_3Sd_2 was deposited as a primary crystallite from certain of the alloys; he referred to treatment of the melt and asked the authors whether the points they had put forward could be accounted for in the lines which he suggested.

Dr. Desch referred to the authors' microsections and found their copper-cadmium equilibrium diagram perfectly satisfactory.

Professor Turner stated that these alloys were now being used on a very wide scale, and one of his students had been working on their physical properties; he would put forward a paper later and this, with the authors' contribution, would increase our knowledge of them. These alloys were difficult to cast solid, but the difficulties could be decreased by precautions in the casting and the use of a suitable flux. One difficulty had reference to blowholes in making the richer alloys for which, however, there was so far no application apart from their use for mixing purposes.

Mr. Jenkins in the course of his reply explained by curves on the blackboard the reason for the suppression of gamma, pointing out that there was a difference in the crystal velocity which perhaps accounted for the occurrence. In regard to the blowholes mentioned by Professor Turner, the authors, he (the speaker) added, were not sure whether the pressure vapour curve crossed the liquidus. Electric conductivity by the addition of cadmium was not suppressed to the same extent as by the addition of other constituents.

Aluminium-Copper Alloys.

The second paper taken on Thursday afternoon's meeting, entitled "The Aluminium-Copper Alloys of Intermediate Composition," was contributed by Mr. D. Stockdale, who read it in abstract. He stated that in a former paper he had described the copper-rich aluminium-copper alloys. Now a diagram was put forward which embodied work done on alloys containing between 16 per cent. and 76 per cent. of aluminium. The methods used had been thermal and microscopic, and the results showed that the alloys formed a very complicated series of solid solutions. The compound, Cu_2Al, had been shown to exist in two polymorphic modifications. A second series of solid solutions, which was stable at high temperatures, was remarkable in that the structure could be maintained even by the most sudden quenching. This series, too, might exhibit polymorphism. The compound Cu_2Al, once formed was extremely stable, and neither copper nor aluminium could dissolve in it. It was also shown that silicon, even in small quantities, exerted a very disturbing influence on the diagram, probably through the formation of the compound, Cu_3Si. The intermediate alloys were all white, and exceedingly brittle. Saturated solutions showed strange twinning effects and were very difficult to polish. It was unlikely that these alloys could be put to any common industrial use, even though they were most resistant to the action of acids.

Colonel Heycock stated that from having seen the work of the author, he knew all the care which the latter had taken with the experimental side. He felt that the author's diagram carried conviction with it, and that it was likely to prove an important contribution to this difficult subject.

Mr. A. J. Murphy found that the portion of the diagram studied by the author offered great experimental difficulties. The diagram in the paper, as it stood, contained several features which were not possible in a binary system in equilibrium. Mr. Murphy criticised several lines of the author's diagram and the field transitions at various points. He asked whether the author believed the supposed peritectic reaction at one line, the line P.Q.E. proceeded to completion with the rates of cooling he employed. In many peritectic reactions a sheath of the product of the reaction formed round the primary solid phase, shielding it from the reacting liquid. In this way some gamma solid solution might be carried over into a region where it would not exist after annealing. From this cause a series of points might arise on cooling curves of supposed pure ϵ which were really due to depressed heat effects in the metastable gamma solid solution.

Dr. D. Hanson agreed with the last speaker and added that the author's annealing times were not sufficiently long, greater care should be taken in arriving to complete equilibrium, and it was difficult to arrive at this with the ordinary methods of annealing. He (the speaker) in collaboration with Dr. Haughton had devised a thermostat furnace in which small specimens could be heated over weeks and months. When this was set up it was easier to manage than the ordinary furnace, watching temperatures by hand. An equilibrium diagram which was not based on long time annealing could not be relied upon. A furnace of the type he indicated should be installed at the very outset. Many equilibrium diagrams were available as far as the liquidus, not for the solidus, and the alloys were, of course, used in their solid state. The solid state had to be investigated thoroughly.

Mr. Stockdale, in replying, said the alloys had taken up a stable form very rapidly, and he was satisfied that his equilibrium was practically correct. The alloys became stable after four hours or so annealing.

The Copper-Tin System.

The third paper had reference to "The Equilibrium Diagram of the Copper-Tin System," by Mr. Tomimatu Isihara, a paper which had been revised by Professor Carpenter. It dealt with a method which consisted in measuring the electric resistance of the alloys at different temperatures, the rate of heating and cooling being slow enough to enable the equilibrium state to be obtained. By means of the breaks in the resistance-temperature curves, the liquidus, solidus, and other transformations were determined.

Colonel Heycock found the paper to cover a wide field, and the equilibrium which it gave of the system contained a large amount of information not contained in the original one which he (the speaker) had put forward many years ago in conjunction with Neville. They (Heycock and Neville) had particularly stated at the time that their diagram was not to be taken as final. A large amount of work had been done upon it since by many workers, who had altered it in detail parts, though, perhaps they had left in the original outlines. In the earlier days the difficulties to overcome were greater than those of the present time. He (the speaker) was interested at seeing investigation now being carried out by the new method of electric conductivity. It was interesting also to see in the region of the alpha solid solution that the author put forward new points which Heycock and Neville did not find between 500 deg. and 600 deg. At other parts the author's diagram differed from the original one particularly at a point marked M. It would have been more convincing to him (the speaker) if the author had shown a few photographs of the alloys he investigated. In the matter of prolonged annealing, nobody was more aware of its necessity than he and Neville. He expressed the hope that the author would complete his contribution on thermal observations by putting in photographs.

Dr. Haughton found the electric conductivity method resorted to a most valuable one, but it had to be used with all the discretion that surrounded all other methods of dealing with alloys. Dr. Haughton laid stress upon the necessity of long annealing, and the author's results were invalidated by comparatively quick annealing. Every investigator of this system had had a diagram very similar to that by Heycock and Neville made many years ago, which showed the accuracy of the methods followed in the early days with the then existing methods. In the author's alpha region, the line noting the solubility of pure alpha would have to be shifted much to the tin end.

The last paper on "The Cadmium-Lead-Zinc System," by Dr. M. Cook, was taken as read, in the absence of the author.

All the authors received the thanks of the meeting for their contributions. The usual thanks to the Institution of Mechancial Engineers for the loan of their premises terminated the proceedings.

The Exothermic Reaction of Portland Cement Clinker Formation.—The British Portland Cement Research Association has issued a pamphlet on the "Exothermic Reaction of Portland Cement Clinker Formation." This discusses the work known to have been carried out on the question of the heat evolved during the process of combination when the component materials of limestone, or chalk and clay are clinkered. The general conclusion is that the research so far done has not yielded data sufficiently definite to command general agreement, and that further experimental work is advisable with a wider range of materials.

POWER STATION OF THE BRITISH EMPIRE EXHIBITION; BOILER PLANT.

MESSRS. JOHN THOMPSON WATER TUBE BOILERS, LIMITED, ENGINEERS, WOLVERHAMPTON.

(*For Description, see opposite Page.*)

Fig. 22.

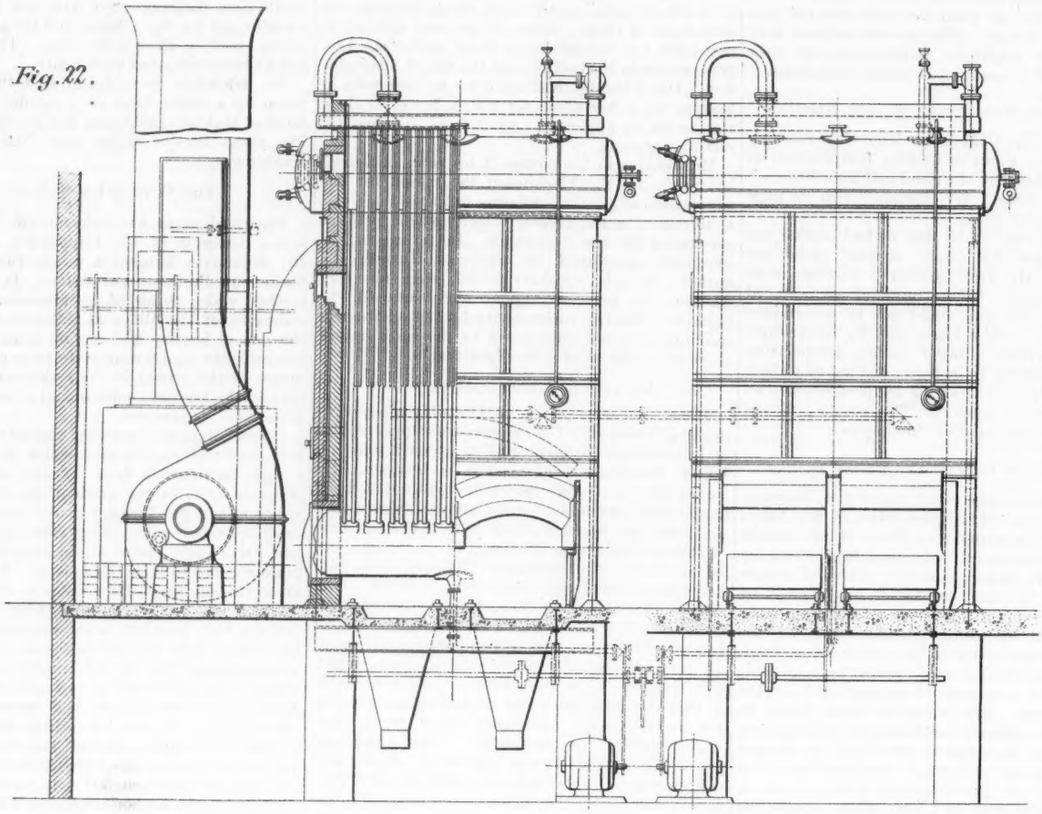
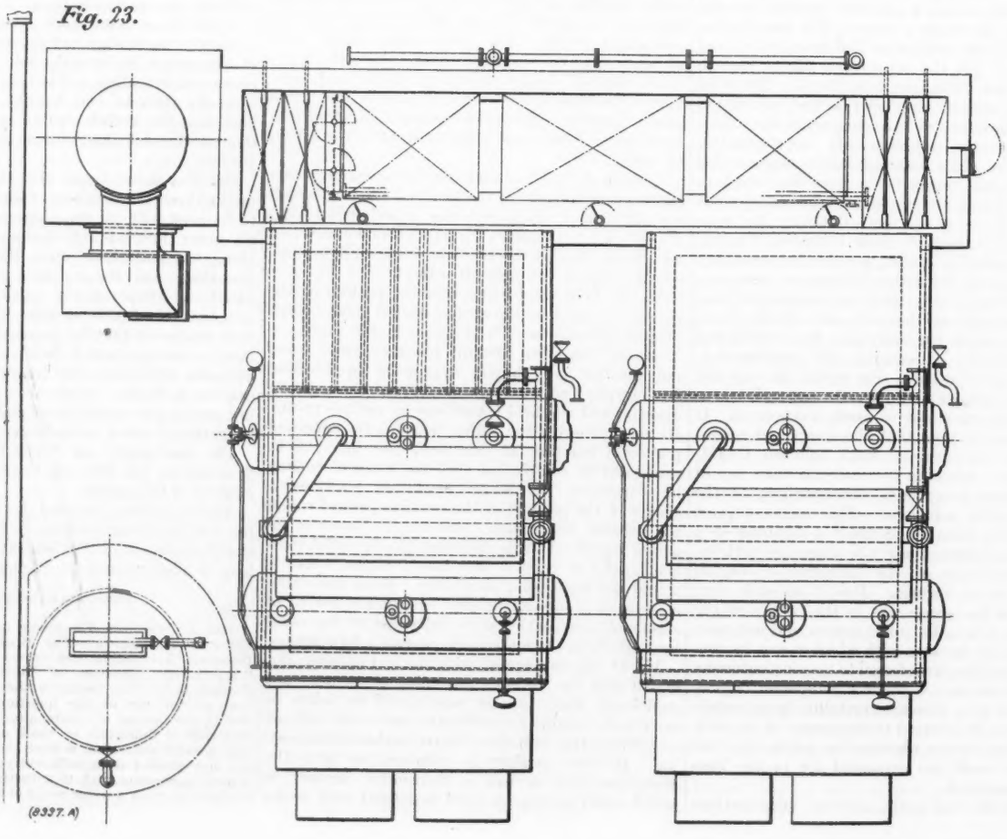


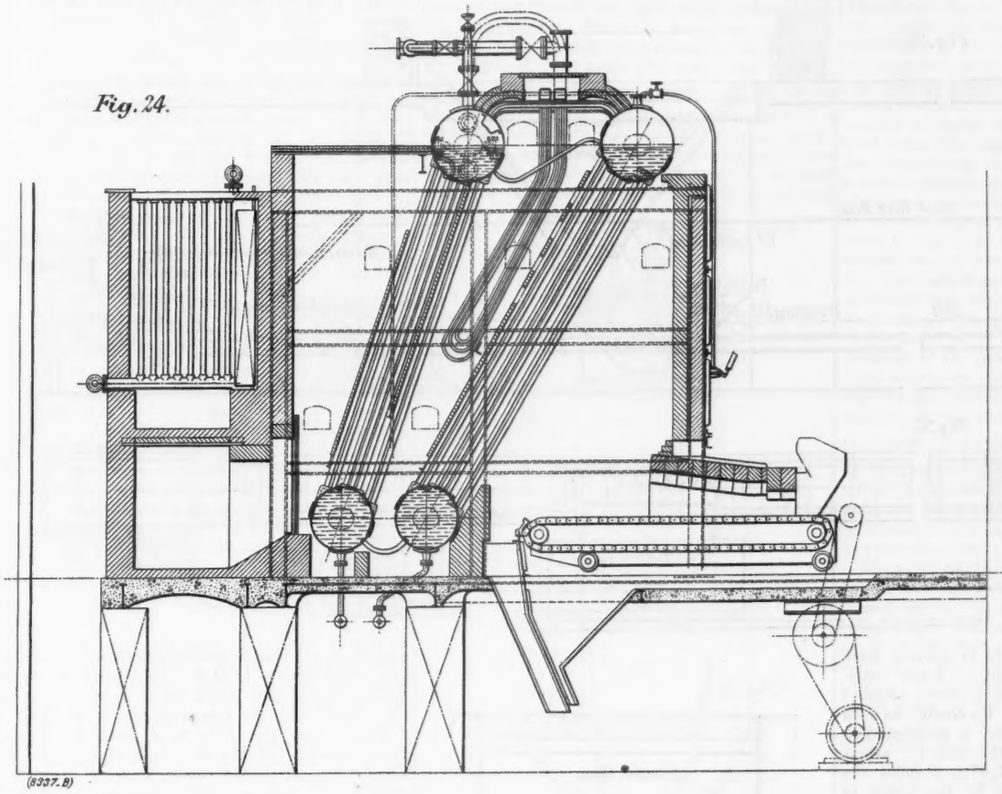
Fig. 23.



BRITISH EMPIRE EXHIBITION; BOILER PLANT.

MESSRS. JOHN THOMPSON WATER TUBE BOILERS, LIMITED, ENGINEERS, WOLVERHAMPTON.

Fig. 24.



(8337.B)

THE POWER STATION OF THE BRITISH EMPIRE EXHIBITION.

(*Continued from page* 335.)

THE pair of boilers supplied to the exhibition power house by Messrs. John Thompson Water Tube Boilers, Limited, of Wolverhampton, are illustrated in Figs. 22 to 24 annexed. Although they are so completely different in type from the Babcock and Wilcox boilers alongside them they fit excellently into the general boiler house scheme, and even a critical observer would not reasonably complain of the appearance of the two types side by side. The Thompson boilers, like the others, are set separate and the pair have their own economisers, induced draught plant and water softening plant, so that their operating results can be separately noted. Each Thompson boiler is of the four-drum pattern with almost vertical water-tubes connecting the upper and lower drums. The arrangement as will be seen from the illustrations allows of the large and high combustion space, which is so desirable, and this feature makes the boilers easily adaptable to a setting for burning powdered fuel. It would have been very interesting had powdered-fuel firing been adopted in connection with at least one of the exhibition boilers, but it was decided to keep to more usual practice in the power house, and all the four boilers are therefore equipped with chain grate stokers by their respective makers.

Each of the Thompson boilers has a heating surface of 4,700 sq. ft., and is capable of a normal evaporation of 20,000 lb. of steam per hour at a gauge pressure of 220 lb. per square inch. The upper drums are each 3 ft. 9 in. in diameter by 17 ft. 6 in. long and the lower drums are 3 ft. 3 in. diameter by 15 ft. 6 in. long, thus giving a very large thermal storage capacity to the boilers. Before leaving the makers' works the drums and fittings were tested to a hydraulic pressure of 500 lb. per square inch, and all tubes to a pressure of 1,000 lb. per square inch. The design is such that any tube may be replaced if necessary without disturbing any other tube or removing any brickwork and no extra head-room is required for the operation. This is an important point in practical operation, and the fact that all the main tubes are straight and nearly vertical, both favours their keeping clean and renders cleaning and inspection easy when necessary. The boilers are supported on a steel framework independently of the brickwork, and all parts are free to expand when working.

A superheater with a heating surface of 956 sq. ft. is fitted to each boiler, and this superheats the steam to a temperature of 600 deg. F. The superheaters consist of a number of solid drawn steel tubes 1·5 in. outside diameter and 0·187 in. thick, bent to shape and machined at the ends for expansion into solid drawn square steel headers. These headers are fitted with special stoppers opposite the ends of each tube for the manipulation of the expander mandrel. The headers are also provided with hand holes to give access to the interior. The superheaters are fitted with stop valves, safety valve and draw valve and the usual superheat regulating apparatus. The steam and water fittings for these boilers generally, including the main junction valves, safety valves, check feed valves, blow-offs, water gauge fittings and high and low water alarms have been supplied by Messrs. J. Blakeborough and Sons, Limited, of Brighouse.

Each boiler, as already mentioned, is equipped with a pair of Messrs. John Thompson's induced draught chain grate stokers 13 ft. 9 in. long by 5 ft. wide, giving an effective grate area of 137·5 sq. ft. for each boiler. The stokers are driven through four-speed gear-boxes of the gate change type. The gear boxes are driven by Brampton roller chains from a line shaft in the basement, this shaft being driven in turn by a 15 h.p. motor supplied by the British Thomson-Houston Company. The drive from the motor to the shafting is through a Westinghouse Morse silent chain. The grates are constructed with the Thompson serrated halved links, and derive their motion from a hollow faced worm wheel and cast-iron worm. The gear box is provided with two clutches, one of which is a safety clutch which will disengage should anything happen to the grate to throw undue strain on the gear.

A separate economiser, built by Messrs. E. Green and Sons, Limited, of Wakefield, is installed in conjunction with each boiler. Each economiser comprises 160 cast-iron vertical tubes 9 ft. long, fitted with the makers' latest soot-scraping gear. The scraper gear is driven by motors through worm reduction gearing. The draught for the two boilers is provided by an induced draught fan of the Sirocco type supplied by Messrs. Davidson and Co., Limited, of Belfast. The fan is 50 in. diameter, and is direct coupled to a 28 b.h.p. electric motor operating on the 415-volt three-phase 50 cycle mains. The fan discharges the flue gases into a mild steel self-supporting chimney constructed by Messrs. John Thompson and Co., Limited. This chimney is 6 ft. internal diameter and 65 ft. high built of plates $\frac{1}{4}$ in. and $\frac{5}{16}$ in. thick. It stands on a 10 ft. brickwork base giving a total height of 75 ft. It is fitted with a ladder on the outside and is surmounted by an ornamental cast-iron cap.

Between the westernmost boiler and the engine room wall is a Kennicott water-softening plant, capable of dealing with 10,000 lb. of water per hour. The plant is 16 ft. high overall and 8 ft. diameter, the main tank being of the same diameter and 10 ft. 6 in. deep. This tank holds 33,000 lb. of water, so that when working at its rated capacity the plant allows at least 3 hours for the chemical reactions to take place. This is an important feature, as the imperfect results of so many softeners are due to the water having to pass through the apparatus too quickly when the plant is working at its rated capacity. In other words, softeners are frequently too small for their duty. In the Kennicott softener the chemicals are added in proper proportion to the hard water supply by means of a float arrangement, and a thorough mixture is ensured by a mechanical agitator. The agitator is operated by a waterwheel running on ball bearings and actuated by the flow of the raw water. The mixture passes down a downtake pipe around the outside of which the treated water slowly rises, and the last traces of precipitated salts which may not have settled are arrested by a wood-wool filter. The sludge formed by the chemical action in the softener, is removed from the tank mechanically, the operation consisting merely in turning a handwheel once every six hours or so, and opening the main sludge valve, whereby the sludge is siphoned away to the drain.

The removal of ashes and clinker from the boiler-houses of power stations is so difficult a problem to solve satisfactorily that great interest will certainly be taken by engineers in the ash-handling plant which has been installed by Messrs. Babcock and Wilcox, Limited, in the Wembley power station. Only those who have had practical experience in ash-handling can really appreciate the difficulties of performing this operation mechanically. Heat, dust, steam, the great abrasive properties of ashes and the corrosive effects they give rise to when wetted all have to be contended with, quite apart from the troubles caused by occasional large masses of hard clinker. Continuous efforts

POWER STATION OF THE BRITISH EMPIRE EXHIBITION; ASH CONVEYOR.

CONSTRUCTED BY MESSRS. BABCOCK AND WILCOX, LIMITED, ENGINEERS, LONDON.

Fig. 25.

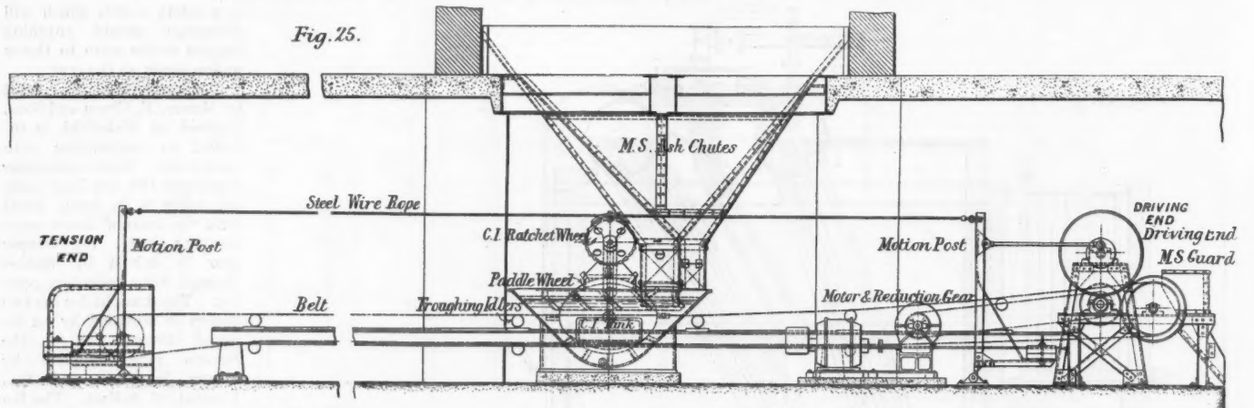
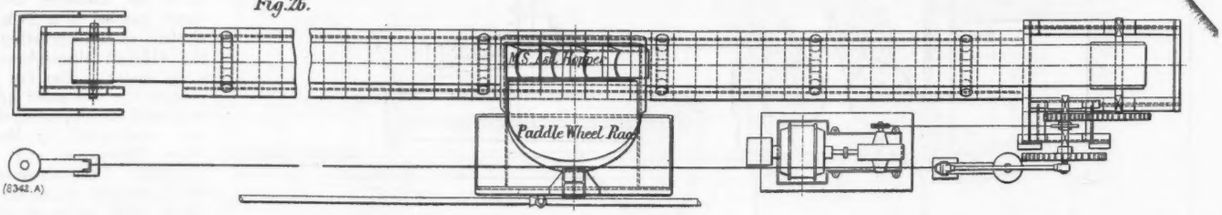


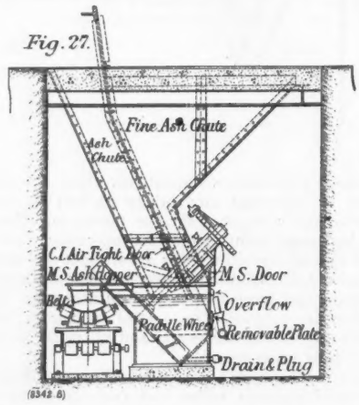
Fig. 26.



have been made of recent years to provide some mechanical device which would be really satisfactory in operation, and the solution adopted by Messrs. Babcock and Wilcox for conditions such as those that obtain at Wembley is illustrated in Figs. 25 to 27 annexed. In this case the ashpit of each of the boilers is fitted with a shoot the lower end of which is sealed by the water in a cast-iron tank into which the shoot descends. The ashes fall down the shoot into the water. In each tank is a cast-iron paddlewheel inclined at an angle of about 45 degrees. This wheel is kept rotating at a speed of about 45 r.p.m., and its paddles lift the ashes from the bottom of the tank and discharge them over the edge when the paddles pass their highest point. They then fall on to a belt conveyor which carries them away.

The paddle wheel runs clear of the tank, so that there are no rubbing surfaces below water and in contact with the ash. The paddle wheel shaft is carried in a long inclined sleeve bearing, fitted with a thrust washer above the tank, the rubbing parts being well out of the way of water and ash. Overflow water from the tank escapes by an outlet on the opposite side of the tank to that from which the ashes escape. The latter, owing to the slow movement of the wheel, are given time for the water to drain from them, before being delivered on to the conveyor. This conveyor consists of a four-ply cotton belt, 16 inches wide, impregnated with rubber. It has a solid rubber face $\frac{1}{8}$ in. thick in the centre, and is supported on idler rollers, the upper set so arranged as to bend the belt into a trough on its working side. The belt runs at a speed of 150 ft. per minute, and is kept taut by a tension gear at the end remote from the delivery point. The conveyor belt is driven by an electric motor with worm-reduction gear and a chain drive to a countershaft The same driving gear also operates a crank-disc the crank pin of which is connected by a wire rope to the ratchet and pawl mechanism carried on the shaft of each revolving ash wheel. Balance weights on the arms which hold the ends of the rope keep it always taut, so that the reciprocating motion imparted to it by the crank-pin causes the slow rotation of the ash wheels by means of the ratchet gears. By throwing the operating pawl of any wheel out of action, that wheel can be stopped without reference to the others, so that only such ash wheels as are required at any time need be kept running. It will be obvious that the type of ash-conveying plant

Fig. 27.



illustrated should possess considerable advantages over scraper-conveyors or similar machines, from the point of view of maintenance cost and replacements.

(To be continued.)

THE JUBILEE OF THE PHYSICAL SOCIETY OF LONDON.

THE Physical Society of London is to-day celebrating the fiftieth anniversary of its first meeting. The fact that physical societies are historically junior to institutions devoted to the study of other branches of science, such as botany, chemistry and engineering, does not, of course, imply any want of early recognition of the importance of physics. It is simply because physical science was almost synonymous with natural philosophy, which in this country was cultivated by the Royal Society (founded in 1662) and by various philosophical institutions of long standing, that we had no physical society in England before 1874. Long before that time many scientific bodies had segregated from the Royal Society, not always with the parental blessing, or had grown up outside it. The botanists had united in the Linnæan Society in 1788; the geologists and zoologists had followed their example in 1807 and 1826; the Institution of Civil Engineers had been founded in 1818, and the astronomers, strong in the Royal Society, had established their own Royal Astronomical Society in 1820. Chemists, after the demise in 1809 of a short-lived Society of Animal Chemistry, had made a more successful start again with the Chemical Society in 1841.

The leading physicists were members of the Royal Society, but the large body of teachers and investigators of physics had no centre of their own until Dr. F. Guthrie, F.R.S., professor of physics at the Government College, South Kensington, proposed to his fellow workers in 1873 "to form a society for physical research, for showing new physical facts and new means of showing old ones, for making known new home and foreign physical discoveries, and for the better knowledge, one of another of those given to physical work." By February 14, 1874, the new Physical Society of London was inaugurated, with nearly a hundred members, in the Physical Laboratory of the South Kensington Museum building, under the presidency of Dr. John Hall Gladstone, F.R.S., a chemist, who would now be called a physical chemist. At the first scientific meeting, held on March 21, 1874, in the same place, Mr. J. A. Fleming read the first paper on a new contact theory of the galvanic cell.

The Society grew at a satisfactory rate, checked soon, however, by the development of electrical, electro-chemical, and radiation sciences, which became powerful nuclei for independent growths. The meetings continued to be held in South Kensington for many years, and the Society returned there after having deliberated for some time in the rooms of the Chemical Society at Burlington House, until it found more convenient quarters in the new buildings of the Imperial College of Science; it has no actual home of its own. Gladstone was succeeded in the presidential chair by Carey Foster, Grylls Adams, William Thomson (Lord Kelvin), Clifton and Guthrie, who had so far been secretary. Other eminent physicists, great men of a great time, followed. The objects, somewhat quaintly formulated in Guthrie's circular letter, were embodied in the articles of association and have consistently been promoted in the widest sense. The Society has certainly taken a notable part in the great scientific development of the last decades, and has kept closely in touch with foreign work. The presidents of the American, French, and German Physical Societies are *ex-officio* Fellows of the Society and many distinguished foreign physicists have been on the list of honorary Fellows.

The papers and discussions are of a high order; demonstrations of novel experiments and apparatus

by members and non-members are encouraged, and the annual exhibitions of electrical, optical, and other physical apparatus have long become one of the scientific events of the year, to which both physicists and manufacturers look forward. These exhibitions were first arranged by Mr. W. R. Cooper when secretary of the Physical Society, now its treasurer. In later years the Optical Society has joined in the exhibitions. The initiation of "Science Abstracts" was largely due to Mr. J. Swinburne and the Physical Society. To foster closer international relations in scientific work the Society has published English memoirs on the works of Helmholtz and of van der Waals. The reports on branches of physics of special and immediate interests, compiled by invitation of the Society, serve the same purpose and have much been appreciated abroad; the recent reports comprise one by Professor Eddington on "Relativity," Dr. J. H. Jeans on "Radiation and the Quantum Theory," and Professor A. Fowler on "Series in Line Spectra." In 1914 the Society instituted the Guthrie lecture, an annual discourse generally delivered in the spring by a physicist from abroad; recent Guthrie lecturers have been R. W. Wood, P. Langevin, J. C. McLennan, C. E. Guillaume, A. A. Michelson, J. H. Jeans, and W. Bohr. The Duddell medal of the Society was founded in honour of William du Bois Duddell, once treasurer of the Society, and a brilliant experimenter whom illness carried away prematurely in 1917. The medal is awarded once a year, without restriction of nationality, for the advancement of knowledge by the invention or design of scientific instruments or by the discovery of materials used in their construction; it was first awarded last month to Professor H. L. Callendar.

The Society is now in a flourishing condition and has more than 600 members on its rolls, of whom 150 have joined during the last five years. It has been singularly fortunate of late in the selection of its officers. At present Mr. F. E. Smith, F.R.S. is president, and Dr. D. Owen and Professor A. O. Rankine its secretaries. Great preparations have been made for the jubilee, which by the courtesy of the Institution of Electrical Engineers, is being held in their building. The reception of foreign and home delegates, and the delivery of the Guthrie Lecture, by the Duc de Broglie, on "The Photo-electric Effect in the Case of High-frequency Radiation," followed by a lecture by Sir. Richard Paget, F.R.S., on "The Nature of Speech," took place yesterday. This afternoon four of the five surviving original members (Professor H. E. Armstrong, Sir W. Barrett, Dr. J. A. Fleming, and Sir Arthur Schuster—Dr. W. C. Unwin is the fifth), as well as Professors C. V. Boys, C. Chree, Sir Richard Glazebrook and Sir Oliver Lodge (all past-presidents), will address the meeting. The proceedings will conclude to-morrow evening with a banquet at the Connaught Rooms; the Duke of York will be present, and the Prime Minister, Mr. J. Ramsay MacDonald, will propose success to the Physical Society of London.

PROPERTIES OF GASES IN HIGH AND LOW VACUA.

ON Saturday last, at the Royal Institution, Sir Ernest Rutherford, F.R.S., delivered the second lecture of his course on the above subject.

He said that on the last occasion he had described the early pioneering experiments on the production of high vacua, and also some of the later air pumps, such as Gaede's rotary mercury pump and his molecular pump. That afternoon he proposed to deal with the latest type of pump, originated by Professor Gaede, which had enormous advantages even over the remarkable molecular pump due to the same inventor. He would also explain how a measure of the speed of a pump could be framed on scientific lines.

Every one now knew that air was an aggregation of an enormous number of molecules, which were incessantly colliding with each other. At ordinary pressures each molecule experienced in every second an enormous number of such collisions. The distance travelled by a molecule between successive collisions was known as the mean free path, and at ordinary atmospheric pressure was of the order of 10^{-5} cm. By suitable air pumps the pressure could be reduced to $\frac{1}{100}$, $\frac{1}{10,000}$; and ultimately to 10^{-10} of an atmosphere. The extraordinarily low pressure last named was quite easily attained with the latest pumps. Since the mean free path of a molecule was inversely proportional to the pressure, the length of this mean free path was about $\frac{1}{100}$ of a centimetre when the pressure was $\frac{1}{1000}$ of an atmosphere; and it would attain a length of a kilometre or more in very highly exhausted spaces. It followed, accordingly, that the properties of these highly rarefied gases differed markedly from those exhibited at ordinary pressures, and these ordinary

Fig.1. GAEDE DIFFUSION PUMP.

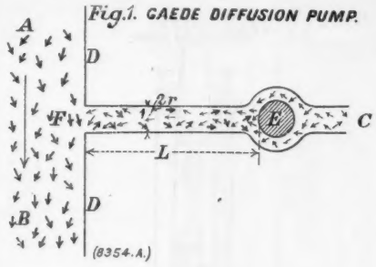


Fig.2. GAEDE DIFFUSION PUMP.

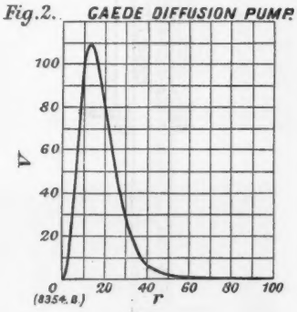
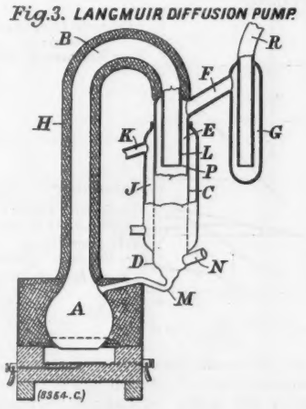


Fig.3. LANGMUIR DIFFUSION PUMP.



properties, he added, were maintained down to, say, a pressure of 1 mm. of mercury. When a gas was passed through a fine capillary tube it experienced a frictional resistance, mainly due to the jostling of the molecules against each other. The resistance in these circumstances was due to the viscosity of the gas. When, however, the pressure of the gas was reduced to $\frac{1}{100}$ mm., the mean free path became comparable with the dimensions of any apparatus used, and the chance of a collision between molecules became very small in comparison with the number of impacts made on the wall of any tube through which the gas might be passing. In these circumstances the frictional resistance experienced was entirely due to the bombardment of the walls, and the laws of flow under these conditions were quite different from those which held at higher pressures. Most of our information on this matter was due to Professor Knudsen, of Copenhagen. The first point to be considered was what would be the nature of the rebound when a molecule hit the wall of the tube at a glancing angle? Would the molecule be reflected like an elastic ball striking a smooth wall? The answer was in the negative. The molecule, in fact, might rebound at any angle with almost equal probability. This was due to the circumstance that in comparison with the size of the colliding molecule the walls of any tube were exceedingly rough. As already stated, any angle of rebound was nearly equally probable, but there was, on the whole, a drift from the high-pressure end of the tube to the low-pressure end, and the rate of flow due to a stated pressure difference could be calculated by statistical mathematics, though not very simply. It was convenient to speak of the resistance of the tube to the flow, and the quantity passing per second was equal to the pressure difference divided by this resistance. At ordinary pressures this resistance was directly proportional to the length of the tube, to the viscosity of the gas, and inversely proportional to d^4 where d denoted the internal diameter of the tube. Hence with very fine tubes the resistance to flow was enormous. At extremely low pressures, however, the resistance became independent of the viscosity and was proportional to the length of the tube and to $\frac{1}{d^3}$, so that it varied as the inverse third power of the diameter, and not as the inverse fourth power, as was the case at ordinary pressures. Along the lines briefly indicated above, it was possible to calculate the resistance of a tube from first principles.

We might next consider the rate at which a gas flowed through a small orifice. In this case it turned out that the resistance was inversely proportional to d^3. Making use of this result, we could allow for the effect of the ends of a tube and calculate completely its resistance from its diameter and length. The foregoing considerations had an important bearing on the use of air pumps of high efficiency, since they pointed to the desirability of using connecting tubes of large diameter.

It was now possible to define rationally the speed of a pump. Thus, let p_1 denote the initial pressure in the vessel to be evacuated, t the time taken to exhaust the vessel, and let p_2 be the pressure finally attained. Then, if p_0 denoted the lowest pressure theoretically attainable by the pump used, and if V were the volume in cubic centimetres of the vessel exhausted, then s, the speed of the pump, was defined by the expression

$$s = \frac{V}{t} \cdot \log_e \frac{p_1 - p_0}{p_2 - p_0}$$

and was thus expressed in cubic centimetres per second.

With the pumps to be described presently there was, Sir Ernest proceeded, no theoretical limit to the final pressure, and with these, therefore, p_0 in the above expression must be taken as zero.

These new pumps were introduced by Gaede under the name of diffusion pumps, and had an extraordinarily high efficiency. They were based on an entirely different principle from pre-existing pumps. They had no moving parts of any kind and their operation was due to the diffusion of the air to be exhausted into a very rapidly moving stream of mercury vapour.

The general idea was illustrated diagrammatically in Fig. 1, where the heavy arrows in the tube F were intended to represent the molecules of mercury-vapour streaming at an extremely high velocity past the side tube shown, which was connected to the vessel to be exhausted. The current of mercury vapour was obtained by boiling mercury in a vessel connected to one end of the down tube AB. This vapour expanded through this tube and was condensed later on by a water-jacket. The mercury-vapour as generated contained no air, and any air molecules entrained by it, in moving past the side tube, were drawn off in the condenser by a "rough" air pump capable of maintaining a fairly high vacuum. It would be evident that any air molecules that passed out of the side tube into the stream of mercury-vapour could never get back again to this side tube, but would be carried away and withdrawn in the condenser.

Whilst air molecules, indicated by the light

arrows, diffused out of the side tube, mercury vapour diffused into this tube and was condensed at E. The problem that arose in designing the diffusion-air pump was to determine the conditions in which air would diffuse at a sufficiently rapid rate out of the side tube into the down tube, where the pressure of the mercury vapour was 10,000 times that of the diffusing air.

Gaede investigated this problem theoretically and arrived at the following expression :—

$$V = \frac{1}{L} \cdot \frac{\pi r^3}{2 \delta_1} e^{-\frac{r P_1}{1520 D \delta_2}}$$

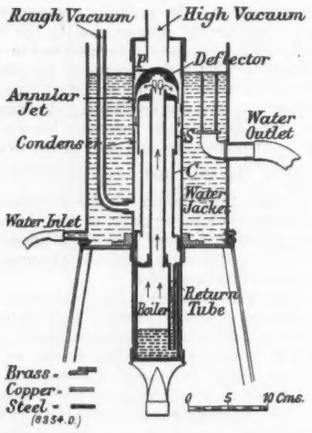
where V denoted the amount of air diffusing out of the tube, L the length of the side tube, r its radius, P_1 the pressure of the mercury vapour, δ_1 the frictional resistance experienced by the gas, δ_2 the frictional resistance experienced by the mercury, and D the coefficient of interdiffusion of the air and mercury vapour.

It would be seen from the formula that V became very small if r was large, but that it also became small when r was very small. Between these two limits there was a maximum for a particular value of r, as indicated by the curve reproduced in Fig. 2. The reason for this maximum lay in the fact that the air had to diffuse past the mercury molecules, which were for their part diffusing into the tube. If the tube were very wide the air molecules met with a very large supply of much denser mercury. If, on the other hand, the side tube were too small, the friction became too great for rapid diffusion. Between these two limits there was a certain size of tube which, if the pressure P_1 was reasonably low, gave a good rate of diffusion. The necessary condition was that the mean tree path of the air molecule between successive collisions with the inward diffusing mercury molecules was comparable with the size of the opening. When this condition was fulfilled the air was rapidly carried away, and there was no limit to the vacuum theoretically attainable. In practice, however, occluded gases were always liberated from the walls of the vessel being exhausted. Gaede produced a successful diffusion pump in 1915, but it worked slowly. This original pump was, however, soon improved.

A year later Langmuir, in America, produced the pump represented in Fig. 3, which Gaede claimed to embody the same principle as his own pump. Langmuir, however, considered that it was based on a different principle, and called it a condensation pump.

The apparatus consisted of a mercury boiler at A. A pipe led from the top of this boiler to the tube L, through which the mercury vapour expanded into the water-jacketed condenser D, from whence it flowed back to the boiler. A "rough" air pump connected to the branch N maintained a fair vacuum in this condenser. At the upper end of the condenser there was an annulus E, which was coupled through the pipe F to the vessel to be exhausted.

Fig.4. ANNULAR JET PUMP.



In a subsequent design Langmuir made the apparatus wholly of metal.

These condensation pumps were very effective from pressures of $\frac{1}{100}$ mm. downwards. As stated, Langmuir held that these pumps were based on a different principle from the Gaede pump, but Sir Ernest thought that if it were not a diffusion pump it ought to be. Langmuir believed that the whole of the mercury in his pump moved downwards and did not diffuse up into the air connection. This, Sir Ernest thought, was stretching Maxwell's law rather beyond its "elastic limit," and that there must be mercury molecules diffusing upwards. Moreover, Gaede stated that the Langmuir pump did not work until, in accordance with his own principle, the mean free path of the air molecules was comparable with the dimensions of the opening.

However this might be, Langmuir's pump constituted a considerable advance, and his work had been followed by others. The condensation pump was simple in form and very useful for rapid exhaustions in the laboratory.

A form developed by Dr. Kaye at the N.P.L. is illustrated in Fig. 4. It was built wholly of metal with screwed joints, so that it could be readily taken apart for examination. The air from the vessel to be exhausted entered at the top and flowed through the outer annulus shown into the wider annular space, through which streamed the mercury-vapour. The condenser was kept free of air by a branch connecting it to a "rough vacuum," as indicated.

This pump was exhibited in action at the lecture, and was shown to be capable of reducing in three or four minutes the pressure in a vessel of 16 litres capacity from $\frac{1}{2}$ mm. to that corresponding to a cathode-ray vacuum. Such a feat would take a long time even with Gaede molecular pump, and with older predecessors would have been an operation extending over several weeks. It was shown that the pump could take charge of and control a considerable leak.

Fig.5. GAEDE DIFFUSION PUMP.

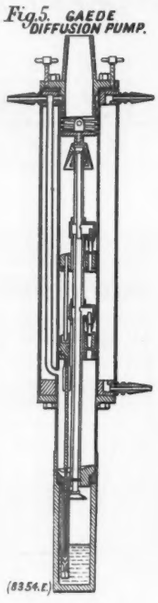
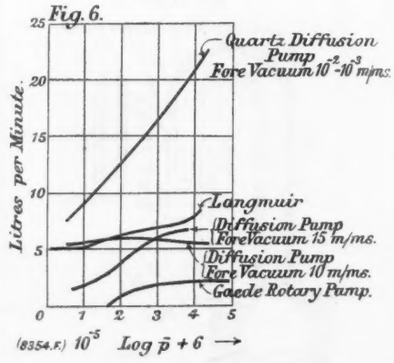


Fig. 6.



Sir Ernest next exhibited in operation the latest form of Gaede pump, illustrated in Fig. 5. This the lecturer said was a three-stage pump and worked well with a discharge pressure of 2 cm. of mercury, which represented a vacuum readily attainable with a water pump. The mercury boiler was shown at the bottom of the figure, and supplied three jets arranged in series. The one at the top acted on the diffusion principle and was coupled directly to the vessel to be exhausted.

The air collected by this jet was withdrawn by a second jet shown at mid-height on the right. This second jet at the outset operated as an ordinary ejector, but as the vacuum improved it began to act on the diffusion principle, and thus maintained a low pressure in the condenser for the main diffusion pump. The air discharged by this second jet was collected by a mercury ejector lower down, and delivered by it to a roughing pump capable of reducing atmospheric pressure to 2 cm. of mercury.

With this series pump it was shown that a few seconds sufficed to produce a cathode-ray vacuum in a very large tube. It was also shown that with this pump quite a considerable difference of pressure could be maintained in two parts of a vessel connected by a narrow tube.

As these pumps worked by diffusion, the speed of working, Sir Ernest stated, varied as the square root of the molecular weight of the gas exhausted, so that hydrogen could be evacuated nearly four times as fast as air. The results of experiments at the Reichsanstalt on the speeds attained by different pumps are plotted in Fig. 6. It would be seen that with the best pumps the "sucking power" was not very different at different pressures.

THE LATE CAPTAIN HAROLD L. THOMSON.

CAPTAIN HAROLD LYON THOMSON, M.I.E.E., who died after a short illness on March 13, was one of the earliest electrical engineers. He was the son of Mr. R. W. Thomson, of Edinburgh, who was well known owing to his pioneer work in connection with rubber and pneumatic tyres. His son inherited much of his father's genius for mechanics. He joined Crompton and Co. in 1880, and designed many early fittings and appliances. Later Crompton's put him in charge of their outdoor installation work. When the new Law Courts were being fitted with electric light, in 1881–82, Thomson was in charge of the work, and most of the switches and pendants, brackets, and other fittings which he then designed and fitted are still in use.

After leaving Crompton's he became Secretary to the Khedive of Egypt, and was at Cairo during the stormy periods of the expedition for the relief of Gordon at Khartoum. During his life at Cairo he studied Arabic and Oriental literature so thoroughly that on his return to England he became a distinguished Orientalist. After his return he became a member of the Westminster City Council, and was alderman, and eventually Mayor in 1912. He was responsible for organising the mechanical transport for the City Council, and when war broke out he went out as a captain in the Army Service Corps in charge of a fleet of their vehicles. Thomson's skill as a mechanic was remarkable; he preserved up to the last that facility in inventive detail coupled with great skill of the fingers which he had shown in the early days at Crompton's.

His death is a loss to his colleagues on the Westminster City Council and to all Westminster residents.

THE CITY OF LONDON ELECTRIC LIGHTING COMPANY, LIMITED.—In the annual report of this company for the year ending December 31, 1923, it is shown that the gross capital expenditure at the end of the year was 3,656,496*l.* Sums aggregating 873,424*l.* have been written off at various times, leaving the net capital expenditure at 2,783,072*l.* The company paid 6 per cent. on the first preference shares, 8 per cent. on the second preference shares and 15 per cent. on the ordinary shares for the year, carrying forward a balance of 33,482*l.* out of a total of 162,632*l.* available for distribution. During the year the company generated 58,595,164 units, of which 22,492,833 were sold for lighting, 19,207,796 for power, 6,808,020 for heating, and 656,170 were sold as bulk supply. The company itself used 3,479,809 units, and 5,950,536 units represented distribution losses. The maximum demand was 40,098 kw., giving a load factor of about 16·6 per cent. The average price obtained per unit sold was 3·49*d.*, as compared with 4·05*d.* in 1922 and 3·28*d.* in 1918.

CASK-WASHING MACHINE.

CONSTRUCTED BY MESSRS. G. HOPKINS AND SONS (CLERKENWELL), LIMITED, ENGINEERS.

Fig. 3.

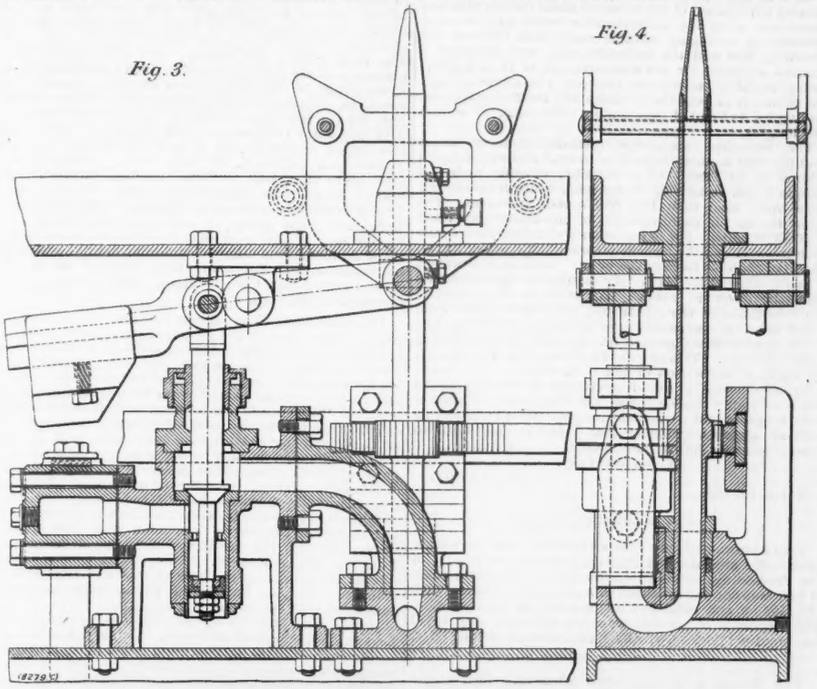


Fig. 4.

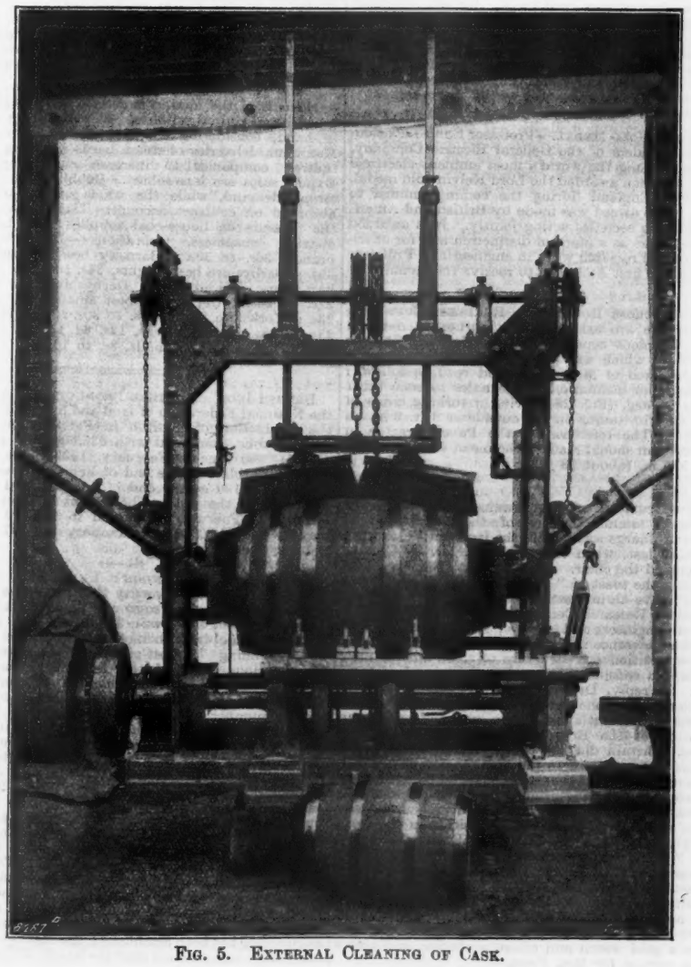


FIG. 5. EXTERNAL CLEANING OF CASK.

CASK-WASHING MACHINES.

THE old processes of cleaning casks are being rapidly superseded by the use of machines. Not only are great economies in time and labour obtained when machines are introduced, but the work done is of a much more satisfactory, consistent, and reliable nature. A machine for the purpose is illustrated on Plate XXVI, on this page and on page 370. This machine is one of the products of Messrs. G. Hopkins and Sons (Clerkenwell), Limited, of 40 to 52, Holloway Road, London, N.7. The process of washing is conducted with steam and hot water or liquor, which is introduced to the cask through the bung-hole. In addition, the rapid agitation of water in the cask is also used, and the outside of the cask is treated for the removal of any adhering material. The machine illustrated is constructed to perform all these operations mechanically and at a speed of from 180 to 240 casks per hour.

In Figs. 1 and 2, Plate XXVI, the general lay-out of the machine is shown. The casks are introduced at the left-hand end of the machine, as it appears in these illustrations. The first operation is to locate the bung. This is done by turning the barrel on four small rollers, in between which there is a spring-supported vertical rod. This rod is held down by the weight of the cask until the hole comes above it, when it enters the bung and holds the barrel in place until it is lifted by a carrier to each of the nozzles in turn in the first half of the machine. The carrier consists of two bearers on which there are stops to prevent the casks from rolling. Motion is taken from a crank, which is turned by a worm wheel erected on the superstructure, to two pairs of brackets fixed to the carrier, and there are cranks at each end of the carrier to prevent it swinging too far. In the course of operation any point on this carrier describes a circle in the vertical plane. When it is swung round with its end underneath the cask the carrier lifts the cask, which is prevented from rolling by the stops. When another half-circle of movement of the cranks takes place, the cask is deposited on the supports each side of the first nozzle. The construction of the nozzles is shown to a larger scale in Figs. 3 and 4. From these figures it is seen that the cask supports are mounted at the ends of two side levers. On the other side of the shaft, which serves as a fulcrum, these levers are loaded and provided with a connection to a simple valve. As the cask depresses the supports the nozzle enters the bung, for the cask has been kept from turning since the bung was first located, and the valve opens which controls the admission of hot liquor to the nozzle, and the cask is thus sprayed inside. When the carrier removes the cask the valve is instantly shut by the action of the load on the other end of the lever. The cask then drains into the channel below the nozzle, and is passed to the next nozzle for similar treatment. The first set of four nozzles comprises three of small opening and one, the last, of greater bore, known as a charging nozzle, which is used to introduce a great amount of fluid. Steam may be introduced through some of the nozzles, but the first and last always deal with liquor. When the cask is lifted from the last nozzle it is allowed to roll over on the carrier, which is here provided with stops on one side only. In turning over, some of the liquor is drained off, but a large quantity is retained and is splashed about inside the cask, as it is shaken about on sets of eccentric supporting discs in the part of the machine known as the rumbler. Here also brushes clean the outside of the cask (see Fig. 5).

After the rumbling is completed the barrel is raised by two curved arms, shown dotted in the middle of Fig. 1. These are brought into action by motion given to two toothed quadrants, which are pulled up at the proper time by the action of a belt from a reciprocating system actuated from one of the overhead cross-shafts. The bung must again be located before further internal cleaning is possible, and as the barrel reaches a set of small rollers which turn it, a similar device to that used at first for the same purpose enters the bung and holds the cask in readiness for transfer to the second set of nozzles in turn. When the actions are all performed the inside of the barrel has been thoroughly and completely scoured inside and out, and can be sent away from the machine in any direction by the use of the small turntable at the end of the machine. The four illustrations on page 370, Figs. 6 to 9, show various stages in the operations. There is no necessity to work with only one size of cask, as the machine will accommodate anything from a hogshead to a firkin, and Figs. 6 and 7 show how the end discs grip against these two extreme sizes. Overhanging loaded arms press the discs against the cask, no matter what its size. Figs. 8 and 9 show, by views of a machine of fewer nozzles, how the cask is brought down over the nozzle and how the lever system changes its position when the cask is in place. The weight of the cask, as already mentioned

is used to open the valve to allow the liquor to pass into the cask.

The machine is driven from a fast and loose pulley, seen at the foot of Fig. 2. Two speeds are obtained for the main shaft, as the two drives may be put into or out of action by the operation of dog clutches. The main cross-shaft is operated by bevels, but the motion given to the carriers is obtained from longitudinal shafting provided with worms.

"THE MAGNETIC TESTING OF SMALL SPECIMENS."

TO THE EDITOR OF ENGINEERING.

SIR,—I was much interested in Dr. Wall's article in your issue of 7th inst. (page 293) on the use of small ring-shaped specimens for carrying out magnetic tests, and particularly in his reference to the cobalt chromium and permanite magnet steels. While I entirely agree with him as to the merits of the method he suggests when applied to steels of low coercive force, I do not think it is quite so generally suited to the testing of the high coercive-force steels, and I would ask your permission to give a brief description of an alternative method which we have developed and which we find extremely satisfactory. As applied to steels of very high coercive force the ring specimen has the following disadvantages:—

1. Difficulty of providing sufficient winding. Dr. Wall overcomes this by immersing his specimen in an oil bath, but even then suggests a current of 168 amperes. A simple calculation will show that this corresponds to some 2 kw. or 3 kw. loss in the winding, while if this current is to be taken from an ordinary 110-volt or 220-volt supply a much larger amount of power is necessary, which, in addition to the fact that such amount may not be available, will involve serious difficulties in control.

2. A ring specimen will not be truly representative of a magnet steel. Most magnet steels show a quite appreciable difference according to whether they are tested parallel to the direction of rolling or at right angles to this. Permanent magnets themselves are invariably designed so that the flux runs in the direction of rolling. The bending of such a small ring specimen from strip and the welding of the ends is, of course, quite out of the question.

3. In a ring specimen there would appear to be a certain amount of uncertainty as to the estimation of the mean length of the flux path to be used in the formula 4π NC = HL. As L on the outside of the ring is very considerably greater than on the inside, it follows that H here is less. Consequently, the value of B is not uniform over the whole of the section of the ring, except in the one case where H is zero.

It will, clearly, only be correct to take the arithmetic mean value of L if B is a linear function of H, which is very far from being actually the case.

In testing permanent-magnet steels, and in particular in the case of the cobalt steels, several of the usual potential sources of error may be neglected, unless, indeed, results of an extremely high order of accuracy are required. Thus the reluctance of the joints at the end of the magnet, if made with a reasonable amount of care, is so low as to introduce only an extremely small error. Again, the magnetic circuit may include an appreciable length of soft iron without introducing any error of appreciable magnitude. This greatly facilitates the design of testing gear which is direct reading and does away with the somewhat slow and unsatisfactory ballistic test.

There are two principal types of testing gear of this description in use. In the first the permanent magnet forms a portion of a magnetic circuit comprising a small moving-coil system carrying a constant known current. The moving coil carries a pointer and is controlled by a spring, and its deflection gives the flux passing in the magnetic circuit. In the second the moving-coil system is replaced by a small armature driven at a constant speed and connected to a millivoltmeter, the reading of which is a measure of the flux.

The instrument we have developed is based on the second of these principles. The armature is a disc of soft iron mounted on a bronze spindle and fitted with a bronze ring round its periphery. It runs with small clearance (0·005 in.) between two blocks of "Armco" iron (99·8 per cent. Fe), which form the pole pieces on which the magnet rests. One brush runs on the spindle and another on the periphery of the disc. The resistance of the disc and brushes is arranged so as to be negligible in comparison with that of the millivoltmeter employed, and any thermal EMFs are avoided by the correct choice of materials.

By keeping the disc of considerable size the flux density in the air gap is kept sufficiently low to avoid putting appreciable reluctance in the magnetic circuit. Such an apparatus is, of course, much quicker in operation than any ballistic test, as B and H are read directly at any time—the former from the millivoltmeter reading, the latter from the current in the magnetising coil. It has, however, another great advantage, viz., that it is possible to make automatic compensation for any air flux in the magnetising coil and also for what may be termed the space flux in the magnet itself, so that instead of reading the quantity $B = H + 4\pi I$, as is usually done, the value of $4\pi I$ is obtained directly. In the very high coercive steels at points approaching saturation the values of B and $4\pi I$ differ appreciably, but it is the value of $4\pi I$ which is generally of most interest.

This compensation is made by interposing a shunt in the magnetising circuit and tapping off the drop in a portion of it, and opposing it to the voltage induced in the revolving disc. The voltage induced in the disc due to the air flux in the coil and the space flux in the magnet, is proportional to the current in the coil, and so also is the drop in the shunt, and it only requires suitable adjustment of the shunt to make these quantities cancel out when the millivoltmeter reads $4\pi I$ directly. Further, by arranging suitable resistances between the revolving disc and the millivoltmeter, and by using a shunted ammeter for the measurement of H and interposing suitable resistances between the ammeter and the shunt, it is possible to make the instrument direct reading for $4\pi I$ and H over quite a wide range of section and lengths.

The standard apparatus manufactured is direct reading over a range from 1 to 10 cm.^{2} and over lengths from 6 to 10·5 cm. It is therefore possible to test a sample 1 cm. square by 6 cm. long, which involves but little more steel than Dr. Wall's ring specimen. The error due to the coercive force of the instrument itself is 16 CGS units. For a specimen 6 cm. long this corresponds to H = 2·67, which is practically negligible on a steel of coercive force of 200 or so. Even this, however, is easily allowed for, as it only requires to be subtracted from the observed value. The error in $B_{rem.}$ due to the reluctance of the joints and apparatus is less than 1 per cent. if reasonable care is taken in fitting, i.e., if the specimens are ground on the ends on an ordinary surface grinder. This also can be allowed for, if necessary, by slight extrapolation of the B.H. curve.

In conclusion, I would apologise for occupying so much of your valuable space, but the testing of permanent magnets and permanent-magnet steels is becoming such an important subject that I feel it only right to draw the attention of your readers to the matter.

Yours faithfully,

E. A. WATSON.

March 12, 1924.

PROCEEDINGS OF THE INTERNATIONAL AIR CONGRESS, 1923.—We are informed that the price of the Report of the Proceedings of the International Air Congress, 1923, is 25*s.* and not 1*l.*, as stated in a paragraph dealing with the Report and published on page 336 of our last issue. The Report is obtainable from the offices of the Royal Aeronautical Society, 7, Albemarle-street, London, W. 1.

THE WOMEN'S ENGINEERING SOCIETY.—The second International Conference of Women Engineers will take place in Manchester from April 2 to 5. British, American and Belgian women engineers will read papers, and visits will be paid to local engineering works and to a cotton mill. A special trip on the Manchester Ship Canal has been arranged for the morning of Saturday, April 5. The Lord and Lady Mayoress are giving a reception in honour of the guests at the Town hall.

THE KELVIN GOLD MEDAL.—Professor Elihu Thomson, one of the founders of the General Electric Company, U.S.A., and among the world's most eminent electrical engineers, has been awarded the Lord Kelvin gold medal, and will visit England during the coming summer to receive it. The award was made by British and American Engineering societies acting jointly. It is awarded every three years as a mark of distinction and for excellence in original research work in engineering. Professor Thomson is the first American to receive this honour.

TRACTION ACROSS ROUGH AND ROADLESS COUNTRY: ERRATUM.—We are asked by the author to mention that the statement concerning the performance of the Pavesi tractor which was published in column 2, page 318, of our issue of March 7 should read as follows: "The maximum inclination of the axles to each other in plan is 35 deg. (Fig. 28), giving a turning circle of about 14 ft. 6 in. radius on the outside or 8 ft. 9 in. on the inside." The reference to the Pavesi tractor in the next column should read, "The mean turning radius is about 5·5 m. (about 18 ft.)."

THE INSTITUTION OF ENGINEERS-IN-CHARGE.—The twenty-fourth annual Dinner of the Institution of Engineers-in-Charge was held in the Holborn Restaurant on Saturday last, when the president, Mr. T. Cooper, M.A., occupied the chair. Capt. H. Riall Sankey, C.B., in proposing the toast of "The Continued Necessity for Research," gave an interesting survey of the work done by the Alloys Research Committee of the Institution of Mechanical Engineers and spoke of the successful efforts of Sir John Dewrance in raising funds for research work on the composition and structure of steel, with a view to obtaining a considerable increase in strength characteristics. In reply, Dr. Alexander Russell referred to the excellent work done in research by individual efforts and hoped for its continuance, as a means of preserving the position of the British Empire in the technical industries. Britain did not compete with some of the other countries in regard to the organisation of research or in the number of the personnel engaged on such work in the various manufacturing concerns, but she had never lacked the exceptional pioneer investigators, who had done so much to preserve her position in the front line of progress. Mr. W. H. Patchell submitted the toast of "The Institution" by contrasting the society as he knew it of old with its present position. To this toast the President replied by showing what the Institution owed to its past and present office-bearers, and particularly to the Hon. Secretary, Capt. Penn, to whom he then presented on behalf of the members a gold watch and chain, a cheque, and also a silver tea service for Mrs. Penn.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Hull Coal Traffic.—A further substantial contraction in South Yorkshire coal trade via Hull is shown in the official returns for February. The total sent to Hull during the month, 434,461 tons, represented a drop of over 82,000 tons compared with February last year. The total decline for January and February in comparison with the relative period of 1923 was 229,000 tons. A shrinkage of 75,000 tons was shown in exports last month as compared with February, 1923, and of 117,000 tons for the first two months of this year as compared with the total for January and February, 1923. The two largest export buyers of South Yorkshire fuel were France and Germany, in that order. Together they took more than half the total tonnage shipped. Germany's share was nearly one-quarter of the whole. The Brodsworth, Bullcroft, Hickleton, Ramcroft, and Yorkshire Main group of collieries contributed over 90,000 tons of the total sent to Hull last month, this being an increase of 24,000 tons as compared with their deliveries during February, 1923. Second on the list were Denaby and Cadeby Main, with a total for the month of 58,000 tons.

Iron and Steel.—The reports to hand during the past week from several of the principal steel and engineering concerns in the Sheffield district serve to emphasise how unremunerative were trading conditions during 1923. Works were kept occupied on home and overseas business, and in the aggregate satisfactory tonnages were turned out, but competition was so keen that the bulk of the orders executed barely covered working costs, swollen as these were by a burden of local rates and national taxes unequalled in any other country. The current position shows a somewhat more satisfactory condition of affairs so far as turnover is concerned. In many instances more business has been booked during the past three or four months than for a long time previously, but there are conclusive signs that confidence is being undermined by the possibility of further disturbance from the labour element. This is most evident in the conditions governing the sale of raw and semi-finished materials. Buying has shrunk to the barest minimum consistent with the covering of immediate needs. Makers of crude steel are up against keen competition from France, Belgium, and Germany. Colliery development in South Yorkshire is providing some nice orders for plant and machinery. The steady growth of house-building in mining areas is responsible for the absorption of increased supplies of ironmongery, pipes, &c. The Yorkshire Engine Company, Limited, are to make five locomotives for the Peruvian Corporation, and four boilers for the Central Cordoba Railway. Electric power plant is wanted for Buenos Aires, and electric travelling cranes are under inquiry from New South Wales.

South Yorkshire Coal Trade.—Failure to arrive at a settlement in the mining negotiations is responsible for a continued run on supplies. Collieries have orders well in hand, considering the shortage of empty wagons. Maximum deliveries of steam hards are going to British railway companies to increase emergency reserves. Export sales are less robust. Cobbles and nuts are in strong demand, while the whole output of slacks is absorbed on contract account. There is no easing in the pressure on house-coal supplies from London and district consumers. Quotations:—Best Hand-picked branch, 36*s.* to 39*s.*; Barnsley best Silkstone, 34*s.* to 36*s.*; Derbyshire best brights, 31*s.* to 35*s.*; Derbyshire best house, 27*s.* to 29*s.*; Derbyshire best large nuts, 27*s.* to 28*s.*; Derbyshire best small nuts, 20*s.* 6*d.* to 23*s.*; Yorkshire hards, 27*s.* to 30*s.*; Derbyshire hards, 25*s.* to 28*s.*; rough slacks, 12*s.* 6*d.* to 15*s.* 6*d.*; Nutty slacks, 12*s.* to 14*s.*; smalls, 8*s.* to 10*s.*

BRITISH IRON AND STEEL PRODUCTION.—According to the National Federation of Iron and Steel Manufacturers, the production of pig-iron in February amounted to 612,700 tons, compared with 636,600 tons in January, and 543,400 tons in February, 1923. The number of furnaces in blast at the end of February was 202, compared with 190 at the end of January and 204 at the beginning of the year. The output of steel ingots and castings in February amounted to 767,600 tons, compared with 694,300 tons in January and 707,100 tons in February, 1923.

UNIVERSITY OF LONDON: UNIVERSITY COLLEGE.—The report of the University College is now issued. It shows that during the session 1922–23 the total number of students enrolled was 3,005. Of the total, 2,490 students came from homes in the United Kingdom; 206, including 75 post-graduate and research, came from various parts of the Empire. From European countries there were 198 students; 28 came from the United States of America. From other countries the largest number, 36, came from Japan. The college has for many years taken an active part in promoting adult education by providing public lectures that are open without fee. Over 9,000 persons attended these lectures during the session 1922–23, the approximate aggregate number of attendances being 20,970. The enlargement and reconstruction of the engineering buildings, begun at the end of 1919, has been continued throughout the year, and is now nearing completion. It includes the provision in the basement of a hydraulic laboratory, to be known as "The Hawksley Hydraulic Laboratory," and a machine tools laboratory Provision has been made for a large new laboratory for civil and mechanical engineering, and a new drawing office has been provided. A new department of chemical engineering has been established, the chemical engineering laboratory being named after the late Sir William Ramsay.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—Business in Cleveland iron is very quiet after the substantial sales recently put through, and with production in excess of needs, stocks are steadily increasing. Makers, however, report that a large proportion of the accumulation at their yards is sold. At the same time, the position is causing no small amount of anxiety, and fear is expressed that unless demand improves further curtailment will have to be resorted to by laying more plant idle. Quotations show little movement. No. 1 is 94*s.* 6*d.* to 95*s.*; No. 3 g.m.b., 91*s.* 6*d.*; No. 4 foundry, 90*s.* 6*d.*; and No. 4 forge, 90*s.*—all f.o.t. makers' works, and f.o.b. Tees.

Hematite.—Demand for East coast hematite is quiet, but with three furnaces fewer in operation output is so reduced that makers may be able to maintain values. Most of them still ask 100*s.* for Nos. 1, 2 and 3, but buyers are not disposed to go beyond 99*s.* No. 1 is put at 6*d.* to 1*s.* above mixed numbers.

Foreign Ore.—Imported ore is lifeless. Quotations are quite nominal on the basis of best rubio at 24*s.* c.i.f. Tees.

Blast-furnace Coke.—Durham blast-furnace coke is irregular and weak in price. Good average qualities range from 27*s.* 6*d.* to 31*s.* 6*d.* delivered here.

Manufactured Iron and Steel.—Little news of moment is ascertainable concerning finished iron and steel. For any overseas trade there is continued keen competition at cut prices, but manufacturers are understood to be adhering to agreed figures for home business, though the following recognised figures are believed to be squeezable:—Common iron bars, 12*l.*; iron rivets, 14*l.*; packing (parallel), 9*l.*; packing (tapered), 12*l.*; steel billets (soft), 9*l.*; steel billets (medium), 10*l.*; steel billets (hard), 10*l.* 5*s.*; steel boiler plates, 13*l.* 10*s.*; steel ship, bridge, and tank plates, 10*l.* 5*s.*; steel angles and joists, 10*l.*; heavy sections of steel rails, 9*l.*; fish plates, 13*l.*; and galvanised corrugated sheets (24-in. gauge, in bundles), 18*l.* 10*s.*

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel Trade.—The outlook in the Scottish steel trade has not become much, if any, clearer yet, and business is still hanging fire. The industrial position is so uncertain that buyers are very loath to enter into commitments amounting to any tonnage, with the result that hand-to-mouth dealing is all too common meantime. The shipbuilding requisitions are not heavy, which is due to the slow revival of the industry and also partly to the amount of foreign material in the market. Black-sheet makers continue fairly well employed, chiefly on old orders, but are occasionally picking up some new lines which are very acceptable. Inquiries are a trifle better, and included in them this week is one for a large tonnage of railway material for India. Home prices are steady, but the prospect of lower quotations tends to keep buying within narrow limits. The following are the current prices:—Boiler plates, 13*l.* 10*s.* per ton; ship plates, 10*l.* 5*s.* per ton; sections, 10*l.* per ton; and sheets, $\frac{1}{8}$ in. to $\frac{1}{4}$ in., 12*l.* 10*s.* per ton, all delivered Glasgow stations.

Malleable Iron Trade.—No change has taken place in the malleable-iron trade of the West of Scotland, and old contracts are responsible for keeping the works moving at the present time. The fixing of new business is still very difficult and inquiries are none too plentiful. In the re-rolled steel branches there is a fair amount doing, but fresh lines would be welcomed. The current price for "Crown" bars is still 12*l.* 10*s.* per ton, delivered Glasgow stations.

Scottish Pig-Iron Trade.—With the smaller output of pig-iron the stocks at the various works are gradually getting less, but when the production is included the supplies are more than equal to the current demand. The trade position has altered very little over the week, and although the usual regular lots are going out, there is a real absence of the orders for large tonnages to which we are accustomed. The unsettled state of the world's markets is the chief cause of this, and until more stable conditions prevail all round the expansion of business is likely to be of a very limited nature. The Continental competition is still being felt here, but inquiries for home grades are, perhaps, a shade better on the whole, and with the offer of cut prices a few fresh lines have been secured. Prices all round have a slightly easier tendency, and the following may be taken as to-day's quotations:—Hematite, 5*l.* 2*s.* 6*d.* per ton, delivered at the steel works; foundry iron, No. 1, 5*l.* 5*s.* to 5*l.* 6*s.* 3*d.* per ton, and No. 3, 5*l.* per ton, both on trucks at makers' works.

Scottish Pig-Iron Shipments.—The shipments of Scottish pig-iron from Glasgow Harbour for the week ending last Saturday, March 15, amounted to 1,235 tons. Of the total 711 tons went foreign and 524 tons went coastwise. For the corresponding week of last year the figures were 2,262 tons to foreign ports and 253 tons coastwise, making a total shipment of 2,515 tons.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

The Coal Trade.—Exports of coal as cargo from the chief South Wales ports—Cardiff, Newport, Port Talbot, and Swansea—in February reached the smallest total for seventeen months. In all shipments amounted to 1,998,605 tons of a value of 2,529,688*l.*, compared with 2,277,460 tons in January yielding a revenue of 2,932,645*l.* The average f.o.b. price in February at 25*s.* 4*d.* was 5*d.* per ton less than in January. The shipments from the various ports in February were as follows:—

From		Tons.	£	Per ton. £	*s.*
Cardiff ...	...	1,230,104	1,580,075	25	8
Newport	...	422,257	543,863	25	6
Port Talbot	...	177,107	200,038	22	7
Swansea	...	169,137	205,712	24	4

Newport was the only port to show an improvement over January, the shipments in February being 46,187 tons more, of an increased value of 55,166*l.*, but the average price was down 6*d.* Exports from Cardiff were reduced by 225,377 tons and 286,657*l.*, but the average value was unaltered. Shipments from Port Talbot were lowered by 57,017 tons and the value by 104,874*l.*, and the average price by 3*s.* 1*d.* per ton. Exports from Port Talbot were diminished to the extent of 42,646 tons and 66,592*l.*, while the average price per ton was lowered by 1*s.* 8*d.* Shipments of anthracite from Swansea amounted to 107,703 tons, compared with 151,714 tons in January, and the total value was reduced from 234,410*l.* to 147,814*l.* and the average price from 30*s.* 10*d.* to 27*s.* 5*d.* per ton. In the meantime the market is firm, with buyers experiencing difficulty in securing supplies as the collieries are fully stemmed, and there are 37 boats waiting for tips. Best Admiralty large coals are firm round 32*s.* 6*d.*, with best steam smalls from 22*s.* to 23*s.*

New Pontoon for G.W.R.—Messrs. Thomas Diamond and Co., Limited, Cardiff, are launching a new passenger pontoon for the Great Western Railway to take the place of the No. 2 pontoon at the entrance to the Cardiff West Dock. The pontoon, which was constructed under the supervision of Mr. James Diamond, a director of the building firm, weighs about 95 tons and is capable of holding about 700 persons at a time.

Iron and Steel Trade.—Exports of iron and steel goods from South Wales last week showed a considerable improvement, the total of 18,871 tons comparing with 2,957 tons in the previous week. Shipments of tin plates and terne plates amounted to 8,750 tons, compared with 2,623 tons; black plates and sheets to 3901 tons, against 105 tons; galvanised sheets to 2,138 tons, against 201 tons; and other iron and steel goods to 4,082 tons, against 28 tons.

THE ELECTRO-HARMONIC SOCIETY.—The last concert of the thirty-eighth season of the Electro-Harmonic Society was held in the Caxton Hall, Westminster, on Friday last. At such a time it is opportune to express appreciation of the excellent work done by the Society in establishing and maintaining social relationships between members of the Engineering profession through the medium of the excellent programme of smoking concerts and ladies' nights it holds each winter. The committee and the Hon. Secretary, Mr. W. E. Lane, 286, Finsbury Pavement House, E.C.2, again deserve congratulations on the success of their season's work.

THE LATE DR. FRANÇOIS BOREL.—Dr. François Borel who died in January at Cortaillod, Switzerland, best known as inventor of the lead-sheath for cables, started his work as a hydraulic engineer. Born at Couvet, in 1842, he was educated at the Zürich Polytechnikum, which he left in 1863. Having worked on the Rhine regularisation at Schaffhausen, he became a professor in the industrial school of La Chaux-de-Fonds while engaged in hydraulic engineering. He then went to St. Aubin as manager of works making telegraph-cables insulated with asphalt-paper and fabric. After ten years of hard work, financially hardly satisfactory, he started teaching again at Grandchamps near Cortaillod. But he continued his experiments on metal-sheathing for cables and in conjunction with Berthoud, a watchmaker, he brought out the first press for lead-sheathed cable at Geneva in 1879. Others were working on the same problem at the time and various lead-cables were soon on the market. But the new Berthoud-Borel works at Cortaillod were quite able to hold their own even when heavy cable for electric power transmission was wanted. His name is also connected with a direct current motor and an electricity meter. He died after a long active and successful life in his eighty-second year.

THE INSTITUTION OF STRUCTURAL ENGINEERS.—At the Annual Dinner of the Institution of Structural Engineers, which was held on Monday last at the Criterion Restaurant, Major James Petrie presided over a very large gathering, including the Earl of Birkenhead, the Right Hon. J. R. Clynes, Sir Charles T. Ruthen, Mr. W. H. Patchell, Mr. J. I. Davidson, Mr. E. J. Partridge, Brigadier-General Mowat, and Captain W. G. Kiddy. Mr. Clynes assured his hearers that the Government was anxious to encourage that form of sanity in industrial quarrels which would show men how much better it was to "talk it out" than to "fight it out," to try to reach a point of agreement mutually acceptable to both sides and enormously beneficial to the nation at large, before a blow had been struck or before an hour of working time had been lost. The toast of "The Guests" was proposed by Sir Charles T. Ruthen and replied to by the Earl of Birkenhead and Mr. P. G. H. Fender. The President, in responding to the toast of "The Institution," proposed by the Rev. F. H. Gillingham, said they were endeavouring to find a quick, cheap, and suitable use of materials in building, to solve the housing problem, and to that end had convened an International Cement Congress, which would be held next month at Olympia.

NOTICES OF MEETINGS.

THE INSTITUTION OF MECHANICAL ENGINEERS: GRADUATES' SECTION, LONDON.—Monday, March 24, at 7 p.m., at the Institution. Informal discussion on "Failure in Metals." Chairman, Captain H. Riall Sankey, C.B., C.B.E., R.E. (ret.).

THE ROYAL SOCIETY OF ARTS.—Monday, March 24, at 8 p.m., at John-street, Adelphi, W.C. 2. Cobb Lecture: "Certain Fundamental Problems in Photography," by T. Slater Price, O.B.E., D.Sc., Ph.D., F.I.C. (Lecture I.) Wednesday, March 26, at 8 p.m., Ordinary Meeting. "The Fishing Industry and its By-Products," by Neal Green.

THE INSTITUTION OF ELECTRICAL ENGINEERS: NORTH MIDLAND CENTRE.—Tuesday, March 25, at 7 p.m., at the Hotel Metropole, King-street, Leeds. Informal discussion. Subjects suggested:—"Desirability of a Standardised Set of Supply Regulations," to be initiated by Mr. A. F. Carter. "Disadvantages of Electricity from the User's Point of View," to be initiated by Mr. T. B. Johnson, and if required, "B.E.S.A. Standards."

THE INSTITUTION OF AUTOMOBILE ENGINEERS.—Tuesday, March 25, at 6.30 p.m., at the Royal Society of Arts, John-street, Adelphi, W.C.2. "The Balancing of Automobile Engines," by Mr. H. C. Rowell.

THE INSTITUTE OF MARINE ENGINEERS.—Tuesday, March 25, at 6.30 p.m., at 85-88, The Minories, Tower-hill, E.1. "Some Notes on the Theory of Lubrication with particular application to the Michell Thrust," by Mr. J. Ward, B.Sc.

THE ASSOCIATION OF DROP FORGERS AND STAMPERS.—Wednesday, March 26, at 7.30 p.m., in the Assembly Hall, Chamber of Commerce, Birmingham. "Drop Forging Practice, Lecture No. 4." "Laps, Their Production and Prevention," by Leslie Aitchison, D.Met., B.Sc., F.I.C.

THE RADIO SOCIETY OF GREAT BRITAIN.—Wednesday, March 26, at 6 p.m., at the Institution of Electrical Engineers, Victoria-embankment, W.C.2. Lecture on "The Possibility of Electrical Television both With and Without Wires," by Mr. A. A. Campbell Swinton, F.R.S.

THE INSTITUTION OF LOCOMOTIVE ENGINEERS (LONDON).—Thursday, March 27, at 7 p.m. at the Engineer's Club, Coventry-street, W.1. "Modern Steam Rail Coaches," by Mr. H. Kelway Bamber, M.V.O.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—Thursday, March 27, at 6 p.m., at Savoy-Place, Victoria-Embankment, W.C. 2. Ordinary Meeting. "The Future of Main Line Electrification on British Railways," by Lieut.-Col. H. E. O'Brien, D.S.O.

THE WEST BROMWICH ENGINEERING SOCIETY.—Friday, March 28, at 7.30 p.m., in the Technical School, West Bromwich. Paper, "The British Empire Exhibition (1924)," by Mr. E. Rawson, A.M.I.Mech.E.

THE INSTITUTION OF MECHANICAL ENGINEERS.—Friday, March 28, at 6 p.m., at Storey's-gate, S.W.1. Joint meeting with the Institution of Civil Engineers to discuss the report of the Joint Committee on "Standard Tests for Hydraulic Power Plants." Presented by the chairman of the committee: Professor A. H. Gibson, D.Sc.

THE JUNIOR INSTITUTION OF ENGINEERS.—Friday, March 28, at 7.30 p.m., at 39, Victoria-street, S.W.1 Lecturette, "Wood-wool: Its Manufacture and Application," by Mr. A. J. Simpson.

THE SOCIETY OF CHEMICAL INDUSTRY: CHEMICAL ENGINEERING GROUP.—Friday, March 28, at 6 p.m., at the Institution of Civil Engineers, Great George-street, S.W.1. Paper, "Kinetic Elutriation," by Mr. L. Andrews, M.Inst.C.E., M.I.E.E.

THE INSTITUTION OF ENGINEERING INSPECTION.—Friday, March 28, at 8 p.m., at the Royal Society of Arts, John-street, Adelphi, W.C.2. Paper: "The Commercial Testing of Internal Combustion Engines, by Mr. Hal. Gutteridge, A.M.I.Mech.E.

THE ROYAL INSTITUTION OF GREAT BRITAIN.—Afternoon lecture: Saturday, March 29, at 3 p.m. Sir Ernest Rutherford, F.R.S., on "Properties on Gases in High and Low Vacua" (Lecture IV).

THE NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS: GRADUATES SECTION—Saturday, March 29, at 3 p.m., in the Lecture Theatre, Neville Hall, Newcastle-on-Tyne. Joint meeting with the North of England Institute of Mining and Mechanical Engineers: "Coast Erosion, particularly on the North East Coast," by Mr. David Woolacott.

DIESEL ENGINE USERS ASSOCIATION.—Friday, March 28, at the Engineers' Club, Coventry-street, W.1., a paper on "Heavy-Oil Engine Indicator Diagrams" is to be read by Mr. J. M. Ferguson.

BRITISH BOILER PLANT FOR COPENHAGEN.—The municipality of Copenhagen has just placed a very large contract for complete boiler-house equipment for the municipal electric power supply station with the Vickers Spearing Boiler Company, Limited, London, an affiliated company of Messrs. Vickers, Limited. The contract includes boilers of 2,000 h.p. each, with economisers, stokers, air heaters, superheaters, mechanical stokers, and all accessories. The whole of this plant will be manufactured in Great Britain. The contract was obtained in open international competition, and was awarded on the merits of the proposal.

CASK-WASHING MACHINE.

CONSTRUCTED BY MESSRS. G. HOPKINS AND SONS (CLERKENWELL), LIMITED, ENGINEERS, LONDON.

(*For Description, see Page* 367.)

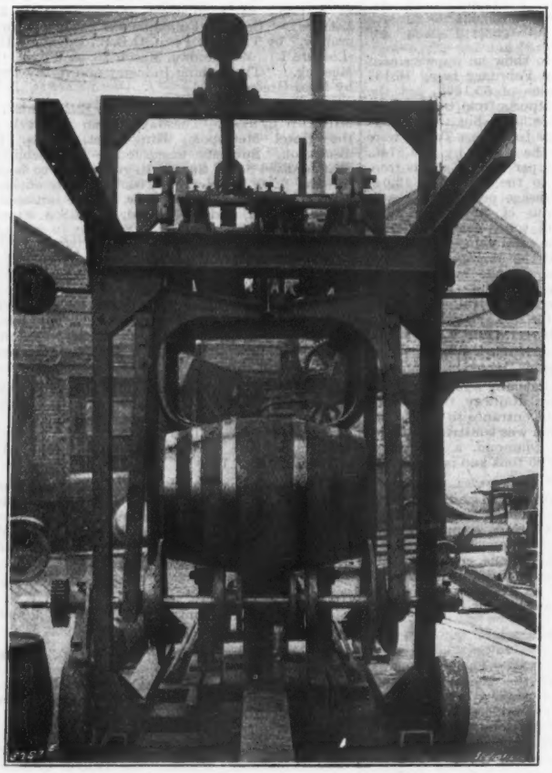


FIG. 6. LARGE CASK BETWEEN THE REVOLVING DISCS.

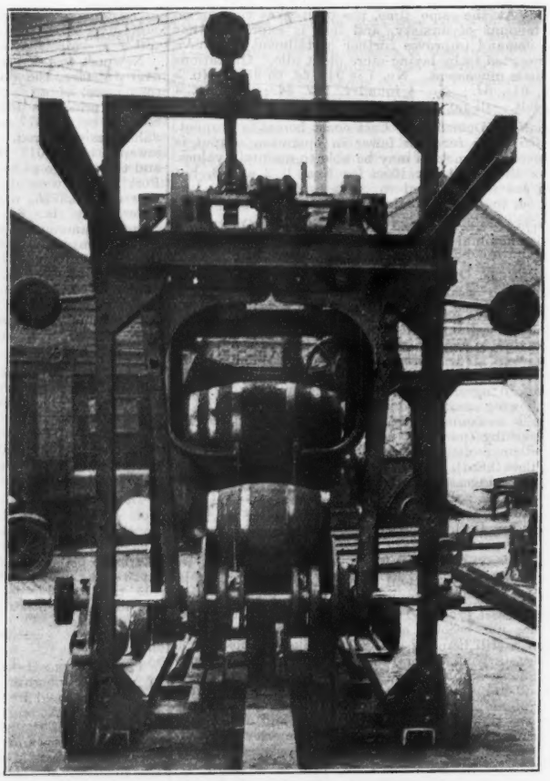


FIG. 7. REVOLVING DISCS PRESSED IN AGAINST A SMALL CASK.

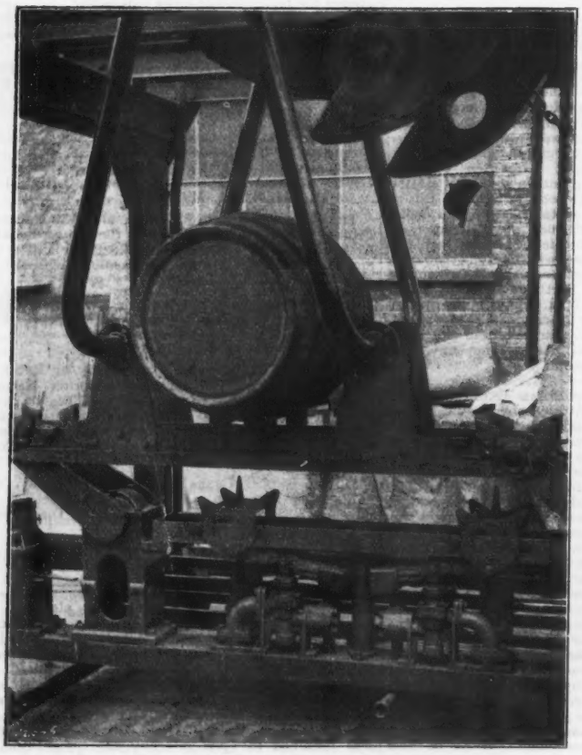


FIG. 8. CASK SUPPORTS FREE AND VALVE CLOSED.

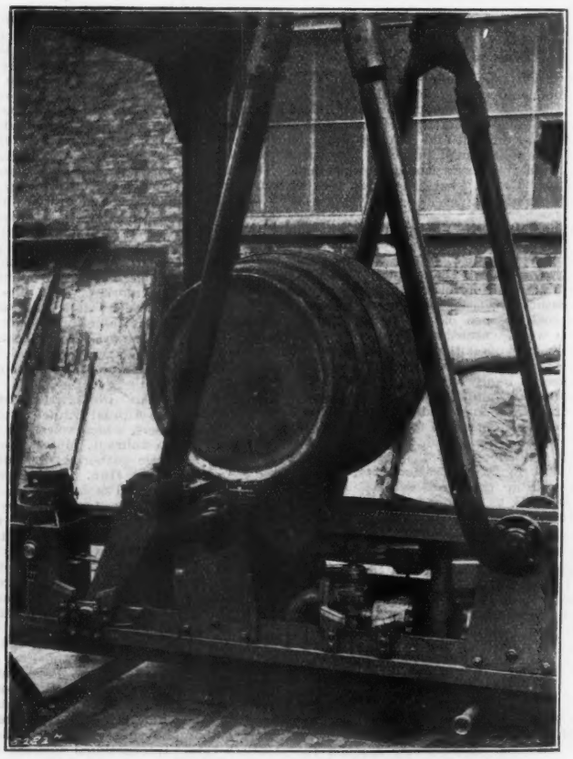


FIG. 9. CASK DEPRESSING SUPPORTS AND TILTING THE LEVER TO OPEN THE NOZZLE VALVE.

CASK WASH M

CONSTRUCTED BY MESSRS. G. HOPKINS AND SO LERKE

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Fig. 1.

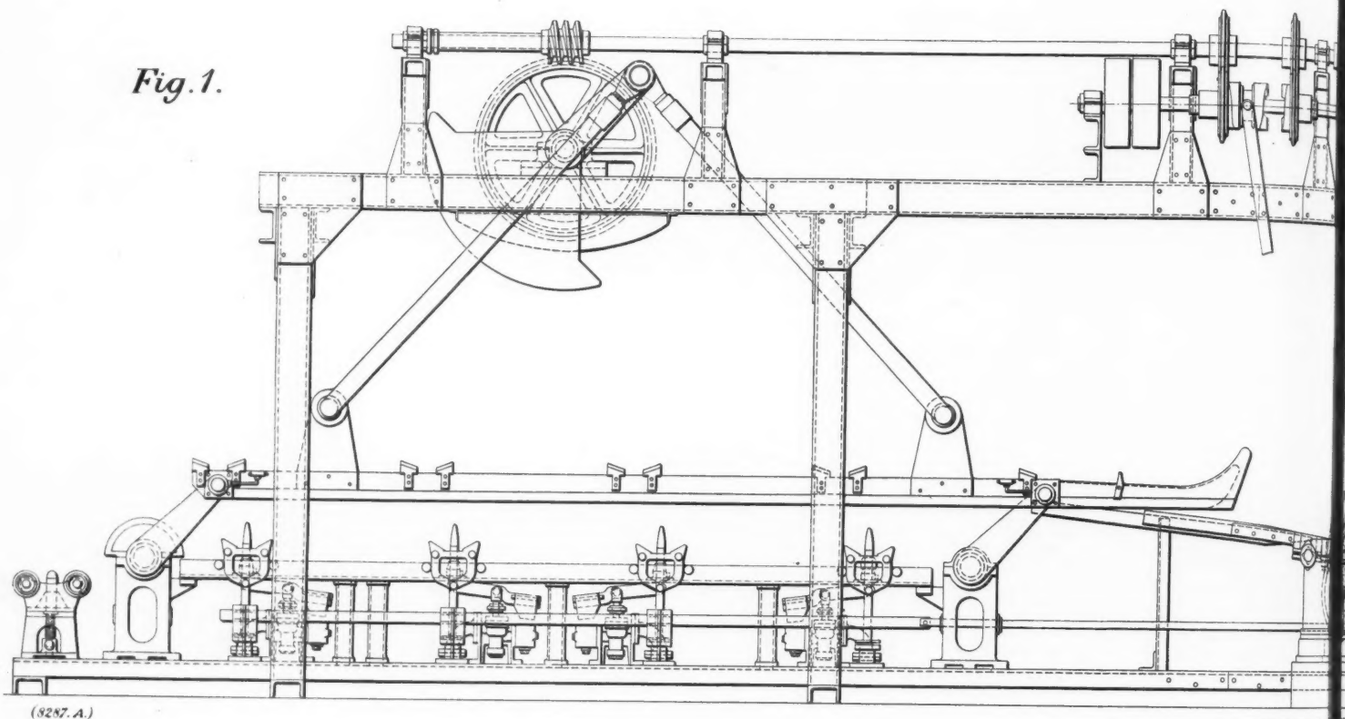

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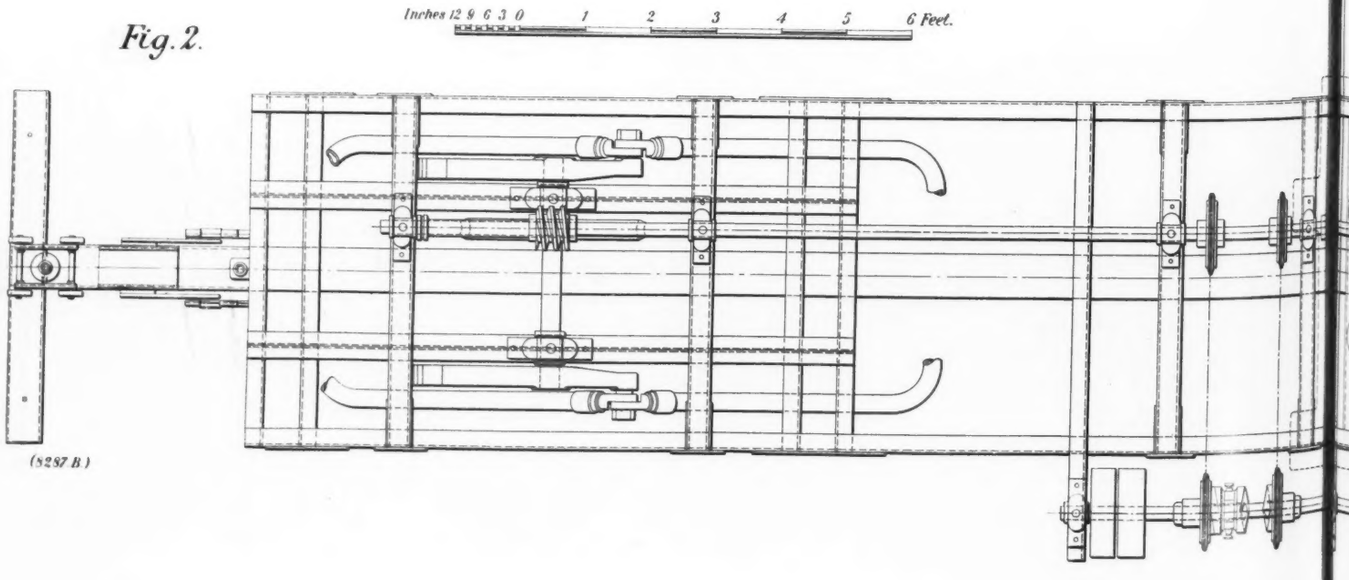
Fig. 2.

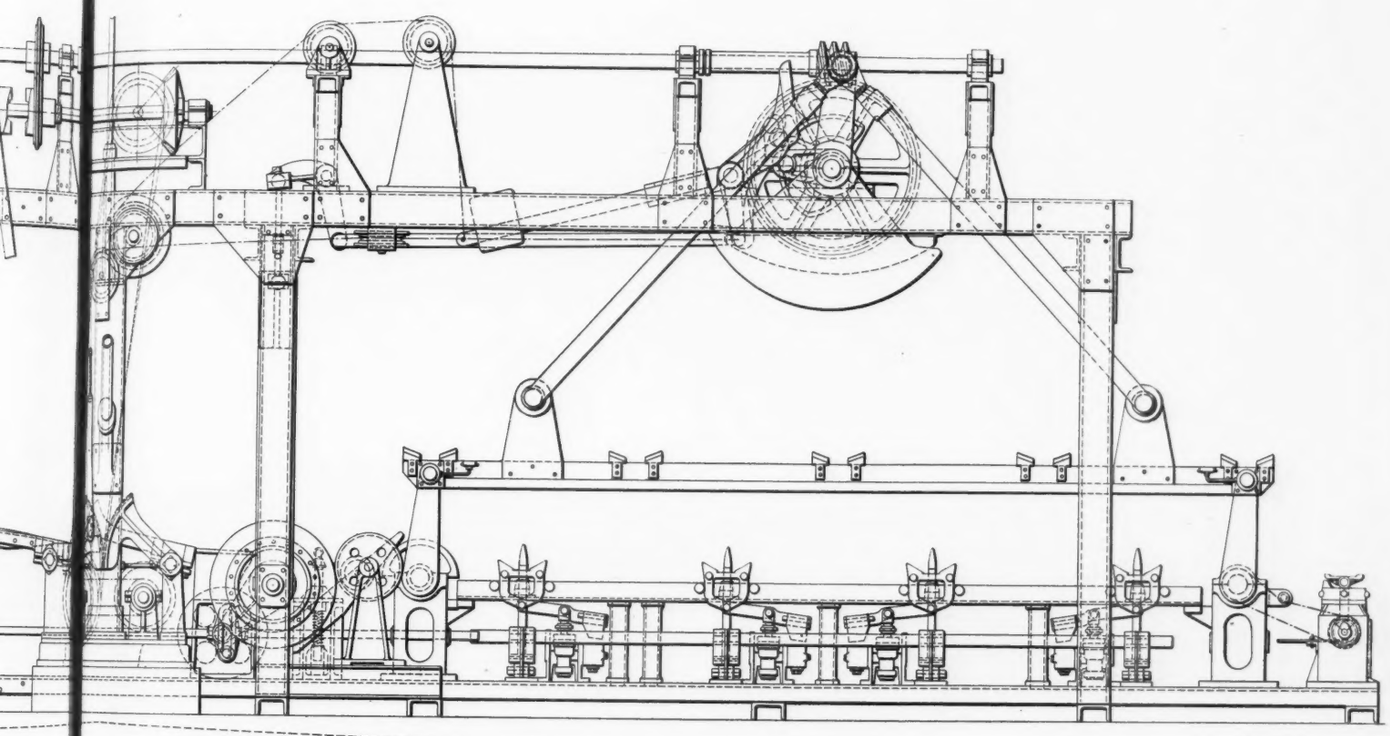


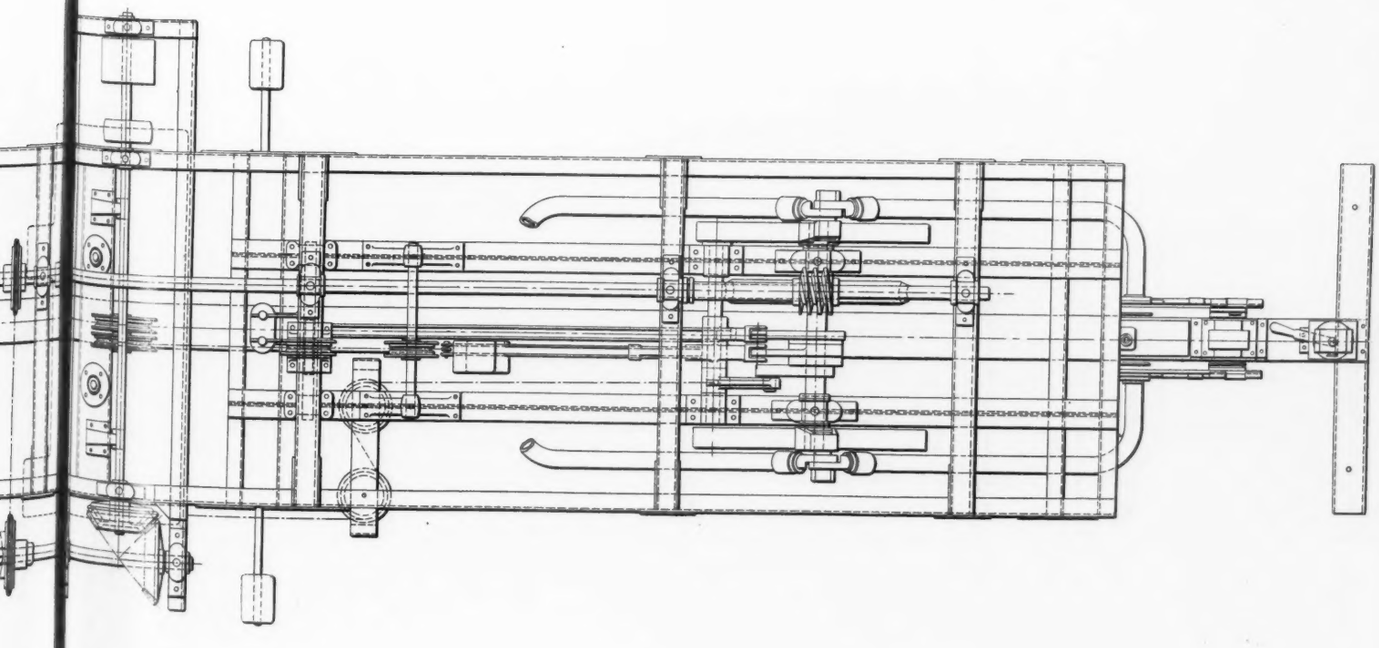
(8287 B.)

WASH MACHINE.

INS AND SO ERKENWELL), LIMITED, ENGINEERS, LONDON.

(For Descripti Page 367.)





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TIME FOR RECEIPT OF ADVERTISEMENTS.

Advertisements intended for insertion in the current week's issue must be delivered not later than First Post on Thursday. In consequence of the necessity of going to press early with a portion of the edition, alterations for standing advertisements should be received 10 days previous to the day of publication.

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Two-Page Plate.—CASK-WASHING MACHINE.

ENGINEERING.

FRIDAY, MARCH 21, 1924.

THE LATE WILLIAM H. MAW, LL.D.

WE are sure that our readers will share our great regret at the announcement of the death, at his residence at Kensington early on Wednesday, the 19th inst., of William Henry Maw, LL.D., who has been closely associated with ENGINEERING from the first day of its publication on January 5, 1866. He had earned the everlasting rest after eighty-five years of life and strenuous work. He was not only the doyen of editors but of engineers, having filled the presidential chairs of the leading British engineering institutions. He has seen pass in succession three generations of engineers, associating with the first with characteristic vitality and energy, leading the second with wide knowledge of every branch of mechanical science, and stimulating the third with experience, judgment and philosophical advice. They were for the profession years of intense ingenuity, of courageous enterprise, of great scientific advancement; and contrary to the usual psychological attributes of advancing years, Dr. Maw was as progressive in temperament towards new ideas as he was intolerant towards proposals based upon long exploded theories. Moreover, for his many bright personal traits of character he was as highly respected as he was greatly honoured.

Mr. Maw was born at Scarborough on December 6, 1838, and was privately educated. In March, 1855, soon after his sixteenth birthday, he commenced his apprenticeship at the then Eastern Counties Railway Works, now the Great Eastern Works, at Stratford, under the late Mr. John Gooch, continuing subsequently under the late Mr. Robert Sinclair. In December, 1859, he became head draughtsman in the locomotive and engineering department at the Stratford Works, and during the following year was also attached to Mr. Robert Sinclair's private staff, being engaged in this capacity on the design of rolling stock for the Great Luxembourg Railway and of locomotives for the East Indian Railway, to both of which lines Mr. Sinclair acted as consulting engineer. These locomotives for the East Indian Railway, designed by Mr. Maw under Mr. Sinclair's direction, were, we believe, the first outside cylinder engines placed on an Indian railway, and, in view of the discussions from time to time as to British and foreign competition in locomotive building, it may be recorded that while the greater number of these East Indian Railway locomotives were built in this country, by the then firm of Kitson, Thompson and Hewitt, now Kitson and Co., of Leeds, and Messrs. Charles Tayleur and Co., of Warrington, a substantial number of them were ordered from Messrs. Emil Kessler, Esslingen, Munich.

In December, 1865, Mr. Maw left the Great Eastern Railway to join the late Mr. Zerah Colburn in the establishment of ENGINEERING. The association of these two began much earlier, because when Mr. Maw was at the Great Eastern Works, Mr. Colburn often visited them, frequently bringing American friends with him. Mr. Maw often showed him round the works, and thus they became well acquainted. During the 1862 exhibition in London, Mr. Colburn decided to write a volume describing the locomotives exhibited, and tracing their development up to that time. It was on one of these numerous visits to the exhibition also that Mr. Maw first made the acquaintance of Mr. (afterwards Sir) Henry Bessemer, who subsequently became keenly interested in the first issue and progress of ENGINEERING. Eventually Mr. Colburn asked Mr. Maw to write the portion of the book on locomotives relating to valve gears, which he did, and this section still remains practically a classic on the subject. Again, when Mr. Maw became President of the Civil and Mechanical Engineers' Society, Mr. Colburn, who had in the interval become editor of our esteemed contemporary, *The Engineer*, printed the presidential address in full. Thereafter it was an easy step from the Great Eastern Works to association in the editorial management of ENGINEERING as colleague of Mr. Colburn, a connection which continued until 1870. Early in that year Mr. Colburn retired from his position in ENGINEERING, and Mr. Maw was joined in the editorship by the late Mr. James Dredge, who had also been associated with the paper since its foundation. Until the death of Mr. Dredge in 1906 ENGINEERING was carried on under their joint editorship, and since then Dr. Maw has continued as senior joint editor.

From the first he set a very high standard as regards the quality of the reproductions of drawings and photographs and the precision and completeness of the descriptive matter. He was, at all times, most progressive in his ideas in regard to engineering science and practice, and, assisted in every way the development of new processes and appliances. Having a splendid memory, he could, with invariable accuracy, give information as to the novelty or otherwise of most ideas, and from his great practical knowledge of mechanical science he was able to advise on the probabilities of any apparatus being a success. He was ever ready, in correspondence, to reply to enquiries. He has helped many to avoid the expenditure of effort and of money in prosecuting experiment and work upon ideas which had been either tried or rejected according to their mechanical fitness. No correspondent ever wrote to him without getting the best advice he could give, and many a student was assisted, particularly in the choice of text books, from his wide knowledge of engineering literature. To all who approached him he was, in every sense of the word, a truly helpful and courteous mentor.

Dr. Maw's activities have not been confined to ENGINEERING, notwithstanding the enormous work he has done continuously as editor. From 1870 until within a few years ago he had an independent practice as a consulting engineer, his work lying largely in connection with engine and boiler construction and the design and arrangement of workshops and similar buildings. Until recently he was consulting engineer for several important firms. Some of these, notably those who entered exhibits for trials at the Royal Agricultural Society Shows and other similar competitions, never sent forward their engines or appliances until they had

been tested and passed by Dr. Maw. One particular phase of his work which has given him great pleasure was the arrangement and laying out of printing works for several of the great daily and weekly newspapers of England, notably *The Daily Telegraph*, *The* (morning) *Standard*, *The Field and the Queen*, and others.

As regards literary achievements other than those in the 116 past volumes of ENGINEERING, and apart from the presidential addresses and papers he read at various engineering and national institutions, he was joint author of "The Water Works of London" and of "Road and River Bridges," while his work "Recent Practice in Marine Engineering" long remained a standard record of developments in this department of science.

For nearly all of the technical institutions throughout the country he was a willing, energetic, and valuable worker. The first scientific institution with which he was connected was the Civil and Mechanical Engineers' Society, of which he was one of the founders in 1859, and President in the sessions 1863–64 and 1864–65. Already reference has been made to his presidential address. This society had the same objects as the present Junior Institution of Engineers and did good work in its time. It passed through considerable vicissitudes and is still in existence, having latterly been amalgamated with the Society of Engineers. It is a noteworthy fact that of the seven members of the first committee all made good. Three of them ultimately became members of the Council of the Institution of Civil Engineers. One (Dr. Maw) became president, another (the late Mr. Walter Hunter) was senior vice-president, and had he lived a few months longer would also have been president; a third was Sir Alfred Yarrow, with whose great career all are acquainted. Other members were Mr. George Estall, who was Chief Engineer of the District Railway for many years; Mr. J. G. Crosbie Dawson, who became Chief Engineer of the North Staffordshire Railway; and Mr. Fred. Cooper, afterwards Resident Engineer of the Forth Bridge. It is noteworthy that 59 years elapsed between Dr. Maw's first presidential address, in 1863, and his last, that to the Institution of Civil Engineers in 1922.

Perhaps, however, the institution which profited most by Dr. Maw's work was the Institution of Mechanical Engineers, to which he was elected a member as long ago as 1873. He became a Member of Council in 1890, was elected a Vice-President in 1896, and President in 1901, serving in that office during two successive sessions. Continuing as Past-President, he served continuously on the Council for over 30 years. His Presidential address to the Mechanical Engineers in 1901 showed not only that full knowledge of current engineering problems and the sound common sense with which he always envisaged them, but an equal grasp of the bearing of optical and other lines of investigation upon the development of engineering science. His remarks upon the training of young engineers and the necessity of the careful study of constructive details as fundamental to a sound engineering education are as true to-day as when they were uttered, and they were typical of his outlook of the profession which he loved.

Every member of the Institution knows the conscientious and energetic service he gave as a Member of Council. His great experience and practical knowledge of engineering, and particularly of experimental work, made it natural that he should be on the various research committees formed by the Institution to carry out work which has been invaluable to the whole profession. Thus, he was on the Marine Engine Trials Committee, and was also a member of the Gas Engine, Steam Jacket, and Friction of Gears Committees. He was chairman of the Committee on Steam Engines. He served for many years on the General Purposes and Finance Committees, being a long time chairman of the latter. But it is scarcely possible to trace all the work he has done for the Institution. This was gracefully and appropriately acknowledged in 1915 by the presentation to him of his portrait in oils, excellently executed by Mr. G. Hall Neale, and exhibited the same year at the Royal Academy. As President of the Institution of Mechanical Engineers he was also Chairman of the International Engineering Congress at Glasgow University in 1901.

He did not join the Institution of Civil Engineers until 1896. Seven years later he was invited to deliver the "James Forrest" Lecture, and many will recall his close analysis of some of the problems of engineering which still remained to be solved. By request of the Council of the Institution, he laid down in this address the lines upon which successive lecturers should deal with problems in their respective branches of applied science. In November, 1911, he was elected a member of council, became vice-president in November, 1918, and was chosen president in 1922. His presidential address will be fresh in the minds of our readers. In a sense it was a sequel to his James Forrest lecture of nineteen years before, and showed what progress had been made towards the solution of those "unsolved problems in engineering" of which he had then spoken. The remarkable thing about this presidential address was the detailed knowledge it showed of recent engineering developments, whether in connection with special alloys, X-ray investigations, steam-turbine practice, or reduction gearing. For such an address to have been prepared, unaided as it was, by a busy man in his eighty-fourth year was evidence of an energy and a living interest in a wide variety of subjects which might well be envied by most younger men. At the termination of his presidency he was presented with an admirable portrait painted also by Mr. G. Hall Neale. Dr. Maw continued to take an active part in the institution until his death.

Among other institutions with which he was associated reference may be made to the Cleveland Institute of Engineers, of which he was elected an honorary member as long ago as 1871. One of the very few papers which he read was contributed to this institution in that year, and was on the subject of "Furnaces for the Production of High Temperature." In 1923, the Iron and Steel Institute conferred upon him the high honour of presenting to him the Bessemer Medal.

Naturally, Dr. Maw devoted a large part of his time to the encouragement of research in every department of science, and it was therefore appropriate that he should become a member of the General Board of the National Physical Laboratory in 1901. He served continuously on this committee until 1915. He was also a member of the executive committee from 1905 to 1909 as a representative of the Institution of Mechanical Engineers, and when the Froude experimental tank was established in connection with the laboratory in 1910 he became a member of the executive committee of this department of its valuable work, and continued so until his death.

For the British Engineering Standards Association he did remarkable work. He was a member of the Committee responsible for the foundation of the association in 1901, and continued until his death to be a member of the main committee and of the Finance Committee of that body, as well as chairman of the committee dealing with Publications and Calculations and of the Committee on the Standardisation of Pipe Flanges. As with all the other offices which he held he was rarely absent from a meeting, and he was invaluable in initiatory work.

Dr. Maw joined the Royal Society of Arts in 1890 and served on the Council as an ordinary member from 1911 to 1914, holding the post of Honorary Treasurer till his death.

During the war he served on many committees appointed by the Government, and particularly by the Ministry of Munitions. He was a member of the Advisory Panel of the Munitions and Inventions Department. He was also a member and, later, Chairman of the Committee dealing with Machine Tools and Mechanical Transport. He also served on the Committee appointed to consider the simplification of the manufacture of artificial limbs. This Committee carried out very interesting experimental work at Imber Court, which, however, was cut short by the conclusion of the war. Further, he was a member of the Ophthalmic Hospital Committee for several years, ultimately becoming vice-president of the institution.

Dr. Maw was almost as well known for his work in astronomy as for that in engineering. He was no dilletante in this branch of knowledge. At his town residence in Kensington and at his country residence at Outwood, Surrey, he had observatories in which he himself has spent many enjoyable hours of his life. These observatories were built to his own design, and the one at Outwood, which was built later than that at Kensington, was entirely built by local labour, he himself making the drawings and the templates for every unit of the dome. This latter was, at the time, unique in respect that the shutter had a counterbalance to suit every position, so that it could be raised or lowered from any position entirely without effort. Dr. Maw read a brief paper before one of the astronomical societies on the subject, and upon its publication he was requested by the Government of one of the Australian colonies, who were then contemplating the construction of a national observatory, to give fuller details. It was only characteristic of him that he should gratuitously make the drawing to suit the shutter of the dome of this national observatory, and he was specially thanked for the success of the application of his system. Dr. Maw was elected a member of the Royal Astronomical Society in 1888, and four years later he became a member of council. In 1900 he was elected the treasurer, and served in that capacity until 1905, when he became President, holding that office for two years, and continuing as Vice-President. He retired from the council in 1919. For many years he was a member of the Library Committee and the Photographic Committee, being joint honorary secretary of the latter. He was also for many years a member of the Joint Solar Eclipse Committee, which was composed of equal numbers of members of the Royal Society and the Royal Astronomical Society. Apart altogether from his contributions to the literature of astronomy, he delivered two presidential addresses, one on the presentation of the gold medal of the Royal Astronomical Society to Professor W. W. Campbell, in February, 1906, and another, on the occasion of the medal being presented to Prof. Ernest W. Brown, in February, 1907, the subject of these addresses being respectively "Stellar Spectroscopy and the Measurement of the Motions of Stars in the Line of Sight" and "Researches in the Lunar Theory."

He was one of the founders, in 1890, of the British Astronomical Association, which has for its special object the encouragement of amateurs to carry out work of real astronomical value. This end was achieved by the organisation of a number of observing sections dealing with special branches of astronomy, each section being under the control of a director having special knowledge of the branch of enquiry dealt with. These directors afforded valuable advice and assistance to the members of their respective sections, and discussed and arranged for publication (if suitable) the observations sent in to them by the members. Under this scheme a large amount of valuable work has been carried out. Dr. Maw contributed to the work of the section devoted to the observation of the moon, of Jupiter, of Mars and of Saturn respectively. He acted as a vice-president of the association from its foundation and held the office of President from 1899-1901, and was many years the Treasurer.

Perhaps his most notable original research in astronomy was connected with double-star observations, which he continued for many years. Between 1889 and 1907 he contributed papers to the Royal Astronomical Society regarding the results of his observations. These are to be found in vols. li, liii, liv, and lvii of the Society's Memoirs. For many years he was a member of the Board of Visitors of the Greenwich Observatory. The following personal tribute regarding Dr. Maw's work in astronomy (sent personally to the writer of this memoir) may be quoted:—"Dr. Maw's work in astronomy may be divided into two great classes. First, he was himself a most indefatigable and skilful observer of double stars. At one time this department of astronomy was much cultivated by English amateur astronomers, and English astronomy had a high reputation from the work done in this direction. But for several years past that reputation had rested almost entirely upon Dr. Maw's observations, for I believe he was latterly practically the only astronomer not professional, either in England or abroad, who devoted himself to this

most important branch of the science with persistency and success. It should be noted that the double-star observations throughout are those of fairly close or very close doubles: not of wide and easy pairs, where it would be a light matter to gather a great number of easy and therefore almost worthless observations. Many of the stars had been almost neglected, and observations had been urgently required.

"Second, the success and usefulness of the British Astronomical Association was due to no single individual more than to Dr. Maw. He was Treasurer to the Association from its commencement, and with its low subscription and heavy expenses nothing but the most unremitting attention on the part of the treasurer would have availed to keep it in a financially sound condition. As treasurer he has necessarily been brought into relation with every member, and most freely gave help, direction and advice in practical observation and in the management of instruments to every member who consulted him, and the number doing so has been very large. Although his principal astronomical observations have been in the department of double stars, they were not limited to that department. He has been an active observing member of the three sections of the Association for the observation of the sun, the moon, Jupiter, and Mars. It is difficult to express adequately the value of the help and support which Dr. Maw has given to the Association as a body and to the members individually."

Dr. Maw was elected a Fellow of the Royal Geographical Society in 1890 and of the Royal Microscopical Society in 1892.

He was also a member of the Board of Studies of the University of London, and in this connection it may be said that in 1909 the University of Glasgow conferred upon him the honour of the degree of LL.D. In presenting him to the Vice-Chancellor, Sir Donald Macalister, K.C.B., for this degree, Professor Smart, after briefly reviewing Dr. Maw's work, said: "It is fitting that our University, situated in what has not inaptly been termed the 'Metropolis of Mechanical Engineering,' should recognise the great services which Mr. Maw has rendered to the advancement both of pure and applied science by admitting him to its roll of honour."

In his life at his country seat at Outwood Dr. Maw found scope for his active and genial qualities. There he had, as already indicated, his observatory and astronomical instruments. In his workshop there were the necessary appliances for engineering handicraft, while in his greenhouse and garden and on his land he found pleasant recreation. He was a characteristic country gentleman and served for many years as churchwarden, with that regard for the observance of the minutest detail of his office which was one of the strong traits of his character; whatever he did he did with scrupulous care. He had the good fortune to spend his last week-end at his country seat.

Photo. by Elliott and Fry.

Yours sincerely
W. Maw

Personally Dr. Maw was a most approachable man. Distinguished engineers from the United States and the Dominions and Colonies almost invariably called upon him when they visited this country in order to introduce themselves to him and to thank him for all he had done for the profession. Rarely was it the case that there was no bond of union. For decades there had flowed across the editorial table a great tide of knowledge of engineering affairs throughout the world. With his most retentive mind, and being an admirable conversationalist, he was able to enter into the professional life of the visitor. Above all his qualities was that of a great raconteur. He had travelled much, met so many great and genial men and had stored up such a mass of happy reminiscence that an hour in his company was amusing as well as profitable. He had often been asked to publish his reminiscences. None more worthy has ever had the same suggestion made to him, none could have produced a volume which would have given more delight; but he could not be persuaded. Many, however, will cherish the pleasure of his companionship and recall his stories, and particularly that merry ripple of laughter which formed an ever-pleasing accompaniment.

A word on perhaps an even more personal note may be permitted to us. Only those who have had the privilege of working under Dr. Maw's direction can fully appreciate that kindliness of nature which made him an ideal employer. In constant contact with his staff throughout the day, his relationship with all was one rather of personal friendliness than of authority, while his natural dignity of character ensured that respect which was his due. His courtesy was invariable. His appreciation of good work was generous and his expressions of thanks were frequent and sincere. Complete master of himself under all conditions, his cheerful equanimity in the face of every difficulty was as wonderful as the promptness and courage with which the difficulties were disposed of. His strong sense of humour and the happiness of his disposition enabled him to derive genuine enjoyment from emergencies which would have disconcerted many a man, and the same characteristics turned every acquaintance into a personal friend. The natural integrity of his character rendered him incapable of any word or thought of meanness, and he will be remembered by all who knew him as an English gentleman, in the highest meaning of the words.

He has left a widow, whom he married on August 25, 1867, and she has reached almost the same advanced age as he did. Of their family three sons and five daughters survive, and to them all there will be extended by many friends the deepest sympathy in their bereavement. A

funeral service will be held at St. Barnabas Church, Addison-road, Kensington, S.W., to-morrow (Saturday) morning at 10.30. The interment will take place at 11.30 a.m. to-morrow at Kensington Cemetery, Hanwell. A memorial service will be held at St. Margaret's, Westminster, to-morrow (Saturday) at 12.30 p.m. Flowers may be sent to 18, Addison-road, Kensington.

BRITISH AND FOREIGN ENGINEERING COSTS.

IN three preceding articles* an attempt has been made to indicate the extent of the abnormal burdens which are at present reflected in British engineering costs and to estimate the likelihood of their remaining at this level or changing in the immediate future. There is, as we have shown, good reason to believe that there will not be a reduction in these burdens. But it has also been suggested that manufacturers have it in their power to do something to counteract the worst effects of increased selling prices. Firstly, they should return once more to a careful scrutiny of the internal organisation and administration of their factories. Secondly, they should take a more active interest in the affairs of the country, municipally and nationally, and ensure that the needs of industry obtain a fair hearing and the priority due to their importance to the national welfare. As the custodians of our industrial inheritance, it is their duty to arouse public opinion to the gravity of our position and to put pressure on their municipal and Parliamentary representatives wherever necessary to deal adequately with the problems which confront us.

A good instance in which such pressure could usefully be applied is that of the reorganisation of our electrical power supply. It is eminently desirable that schemes for the relief of unemployment should pay for themselves and should, when completed, leave the nation with a substantial asset in return for any risk or expense incurred in the execution of the scheme. It would appear highly probable that both of these requirements would be assisted by a well-planned scheme of railway electrification. This would also help to relieve congestion and therefore, to some extent, the housing problem, and it could hardly fail to contribute to the efficiency and cheapness of transport. The effects of this last factor alone in helping our industries labouring in the face of foreign competition cannot easily be over-estimated. When it is realised that a great many such schemes are fully worked out and have the highest expert endorsement both as to their practicability, utility and remunerative qualities, and when it is considered that they have failed to be put into practice more, according to the view of many, through lack of enterprise and public apathy than from any other reason, it will scarcely be denied that the above suggestions are pertinent.

It is not, however, to be supposed that their adoption would remove all our difficulties, nor was it our intention in putting them forward to pretend that so complex a problem is capable of any easy solution. But if they are no panacea, these suggestions would, we believe, if carried out, be an important contribution to the adjustment of our internal troubles. Moreover, when we turn to the consideration of conditions under which our competitors abroad are operating, it becomes clear that there are here also other parallel suggestions of no less importance to be made. Within the short space of a month we have had several notorious examples of important contracts, some of them within the British Empire, being placed in various European countries. In one case an Indian contract for locomotives was placed in Germany, where the tender was 40 per cent. below the British tender; in another, an Egyptian contract, also for locomotives, was placed in Italy, where the foreign tender was 25 per cent. lower. A Belgian firm, again, was successful in obtaining a Bradford municipal contract for electrical gear by tendering 34 per cent. below the lowest British tenderer, and the other day we saw a contract lost on a 70 per cent. difference in price. These instances have only been taken because they are striking and they are recent. Unfortunately, their number could be multiplied.

* See pages 273, 308 and 340 *ante*.

Abnormal conditions with regard to foreign competition, such as those reflected in these contracts, will, clearly, not be materially altered by the most thorough adoption of the expedients advocated above. These expedients could not, on the most optimistic basis and in the most favourable examples, reduce our costs more than 10 per cent., and there would still be much leeway to make up before we could overcome the 40 per cent. barrier which exists against us. It may therefore be as well to inquire into the causes which make this barrier possible, in the hope that at the best some conclusion may be reached as to how they can be removed, or at the worst their true nature may be realised.

Perhaps the most outstanding of all these causes is the difference between the burden of taxation in this country and abroad. The effect of taxation in this country and its incidence on the engineering industry has already been discussed,* but Table I, taken from a recent statement by the Chancellor of the Exchequer, gives an illuminating comparison of British and foreign taxation:—

TABLE I.—*Taxation per Unit of Population.*

—	1913–14 (actual).	1923–24 (estimated).
	In £ Sterling at par.	
	£ s. d.	£ s. d.
United Kingdom	3 11 0	15 18 0
France	3 7 0	6 18 2
United States* (Federal) ..	1 7 11	6 14 10
Italy	2 2 8	3 6 11
Germany* (Reich)	1 10 8	4 1 4

* It will be observed that the figures for the United States and Germany show the expenditure of the Central Government only. They do not include the expenditure of the States, for which information is not available.

This table speaks for itself, and we may without further elaboration turn to the question of wages.

Here the same tendency is in evidence. In almost every case we find our competitors in engineering with a substantially lower wage rate than our own, the only exception being the United States, where exceptional circumstances tend to reduce the balance apparently so much against them. Tables II and III would go a long way to explain the 40 per cent. difference in tenders were there no other causes to be considered:—

TABLE II.—*International Rates of Wages in the Engineering Industry*, 1922.

(In pence per hour: based on Exchange rates on London.)

—	U.S.A.	Britain.	France.	Belgium.
Machinists	31	14½	14	11⅞
Lathe hands ..	28¼	14½	15½	11½
Fitters	—	19	13¾	11½
Smiths	31	—	15⅞	11¼
Iron moulders ..	—	15	13	—
Pattern-makers ..	45	15½	—	11¼
Average skilled ..	36	14⅞	12¼	11⅛
Average unskilled ..	28¾	10¼	8½	7¼

TABLE III.—*Comparison of Competitive Powers According to Wages*, 1922.

—	U.S.A.	Britain.	France.	Belgium.
Skilled	314	128	108	100
Unskilled	400	141	117	100

Owing to the fluctuations of the mark it has not been possible to include Germany in these tables at the same date as the other countries. It would not in any case be desirable to do so, as the wage position in that country has recently been altered. By the imposition of taxation and stabilisation of her new currency German industry is now able to pay wages on a stable basis. Advantage has been taken of the general satisfaction arising from this to pay extremely low wages, skilled fitters now being paid at the rate of 6*d*. an hour for a 60 hours' week.

The capitalisation of industrial concerns is not susceptible of tabular statement, nor is it easy to obtain sufficient information to make useful comparisons. In Germany, however, prudent steps have been taken during the last few months to rehabilitate industrial finance. The capitalisation of all industrial undertakings has been reduced by two-thirds, while Government holdings in industry have been reduced by 85 per cent. It would be outside the scope of this article to attempt to appreciate the merits of so drastic a measure, but its effects on production costs are too obvious to need elaboration.

* Vide page 340 *ante*.

In the domain of general equipment and the organisation and administration of factories, it will scarcely be denied that Germany and the United States in particular, and France and Belgium to a less degree, have made much progress in bringing their standard up to our own. Germany made it a first charge on reconstruction to bring up to date and perfect her industrial equipment. France and Belgium, as Mr. Lloyd George said last year, have not only restored their devastated regions, but have reconstructed their entire countries in the matter of power, transport, and industrial equipment.

In this connection we may revert once more to the matter of railway electrification. The following extract from a leading article in our issue of August 3, 1923, may be quoted:—"France is spending vast sums of money on main line electrification; Holland has decided to start electrifying her main lines; Italy has carried out electrification on a large scale and further works are in progress; Switzerland is hard at work converting the whole of her railways to electric traction—some 500 km. are already electrified and a further 1,100 will be completed by 1928; while Germany has electrified or is electrifying 800 miles, Austria 500 miles, and Sweden 280 miles." Altogether in Europe there are 3,240 miles of electrified track, and in the United States 5,300 miles as against 350 miles in this country, the later being almost entirely suburban. The reduction of transport costs which follows sound electrification is sufficiently well known, and it will be clear that in this branch of equipment much still remains to be done.

These are not, of course, the only factors which go to make foreign costs lower than our own. The lower standard of living in its broadest aspect accepted by workers in some foreign countries, and collapsed exchanges in others, outweigh everything else in importance and are, in fact, largely responsible for the other factors we have mentioned. The problem of the exchanges will only be solved when a general settlement of Europe is reached. It would be no small contribution to that settlement if British manufacturers as a whole were to declare themselves unreservedly on the side of stability. Before they can do this they must realise that it is necessary to lay aside prejudices and approach these questions from a purely industrial point of view. In the past the British manufacturer has been able to indulge his international prejudices and sympathies in the certainty that business will not suffer as a consequence. That time is now passed and the world is in practice, not only in theory, an economic unit.

It is, unfortunately, true that in some countries whose finances are comparatively sound a compensating disadvantage to us is present in a lower standard of living, and *vice versâ*. Germany, for example, owing to the low rates of wages, has been content until recently to adhere to a 48 hours' week. In France, Sweden, Holland and Switzerland, however, the Washington Convention on hours, which was accepted in 1919, when the power of labour and the progressive spirit was at its zenith, has been attacked with determination by industrialists. In these countries the eight-hour day has been reduced from an active piece of legislation to a pious aspiration. In so far as we have accepted the eight-hour day in practice we have already felt the effects of lower competing costs from this cause in the absence of increased output per unit of time worked, and it is to be anticipated that the new legislation now being introduced, which will put the eight-hour day on to a statutory basis, will accentuate this handicap. Without suggesting that the future of industry lies in the prolongation of the working day, there can be no doubt that the imposition of so rigid a scheme will weaken the elastic quality which is so vital to industry in meeting economic adjustments. This handicap will at first be severe, and can only be overcome in the absence of any new factors arising, by attention to

such matters as standardisation, scientific management, and the study of marketing as a science.

Not only should a watch be kept on what the world is doing on the commercial and technical sides, but intelligent and active co-operation, both industrially within the works and politically, should be maintained to anticipate and counter the activities of our competitors. It may be hazarded that the addition to many staffs of minds trained in the world aspect of economics would not prove a bad investment. Individual firms would find, perhaps, that it would repay them to adopt a method of which the Germans have made great use with regard to the training of their representatives. For many years it has been an extensive practice in Germany to send young men abroad to the countries in which they are expected to represent the firm for five or six years, so that at the age of 16 they have mastered two or three languages. After returning to their own works and mastering the technicalities of the business, they are able to render far more valuable services from their knowledge of the languages and customs of the countries to which they go.

We must, then, face the fact that this country has no prescriptive right to the industrial supremacy of the world. During the last century we were in a fortunate position in that we had practically a monopoly in many of the staple industries. This is no longer the case, and every day other countries are increasingly becoming self-supporting. It will be said, no doubt, that these factors are beyond the control of the British manufacturer. To some extent this is true, but to that extent it adds to, and in no way detracts from, the force of the conclusion that our industries must equip themselves more thoroughly in order to operate successfully in their new environment.

To recapitulate, the difficulties through which we are passing are not altogether ephemeral nor entirely the aftermath of the war. Long before that catastrophe industry was becoming more and more the prime factor in the prosperity of civilisation—the war has at most only accelerated this tendency. In other countries it is recognised that industry must and will be served. In Great Britain also the day is past when her industry can be dragged with impunity at the tail of politics. Yet if our manufacturers concentrate upon all that tends to lower costs and increase efficiency, if they take an active interest in public affairs and the regulation of the expenditure of public funds by the more efficient representation of industry on Boards of Guardians, municipal bodies and in the House of Commons, if they recognise that the industrialist, no less than the politician, must have a policy which implies an intelligent executive staff competent to give effect thereto, the genius of the British engineer and the sterling qualities of the British workman will not fail to assure our pre-eminence in the future as in the past.

THE NAVY ESTIMATES.

THE improvement in the naval situation which has followed the destruction of the German menace and the ratification of the Washington Treaty by all the Signatory Powers is clearly reflected in the Navy Estimates for the ensuing financial year. The proposed net expenditure of £55,800,000 for 1924–25, is less by £2,200,000 than the estimates for the current year, and does not greatly exceed the net estimate for 1914–15, which was £51,550,000, the latter estimate having been prepared, considerably in advance of the outbreak of the war, by Mr. Winston Churchill, who was then First Lord in Mr. Asquith's Government. To compare the present estimates with those for pre-war times it is necessary, however, to make allowance for the higher wages now paid and the increased cost of materials, and this, we gather from the First Lord's statement, amounts to about 62 per cent. The 1924–25 estimates would thus be equivalent to an expenditure of about £34,500,000 in pre-war time, this figure being only 67 per cent. of the 1914–15 estimates and being about equal to those for the year 1903–4. It thus appears that our present naval expenditure is roughly equal to that considered necessary before the British Fleet had to be concentrated in home waters and expanded to meet the threatened attack from Germany.

In his statement, the First Lord made it amply clear that the estimates have been framed merely with a view to the maintenance of the one-power standard which has been accepted as the naval policy of the country, this policy being continued with particular regard to the need for national economy. Work on the battleships Nelson and Rodney will, of course, be continued and the 1924–25 programme includes the completion of the cruisers Effingham, Frobisher and Emerald, which have been greatly delayed, as well as the completion of the flotilla leaders Keppel and Broke, three destroyers and five submarines. Work on the cruiser Enterprise, the minelayer Adventure and the submarine O.1, will be continued. Apart from these, the only new construction provided for is the commencement of five cruisers and two destroyers for which a sum of rather less than £1,800,000 has been allocated for next year. This is a very material curtailment of the programme of the previous Administration, who, as recorded on page 116 *ante*, proposed to lay down eight light cruisers, three submarines, a submarine depot ship, two destroyers, a destroyer depot ship, ten gunboats, an aircraft carrier and a mine-layer. These vessels, it was understood, were urgently needed, and it was hoped that their construction would have afforded some relief to the unemployment problem.

It should be mentioned, however, that, at the request of the late Government, the Admiralty have placed orders for materials and stores to the value of about £500,000 with contractors in areas in which unemployment had been most serious, and these orders are expected to give employment to some 7,000 men for 17 weeks. It has also been decided to place orders for machinery valued at £400,000 with the same object in view, and to meet the needs of Barrow-in-Furness, where unemployment has been particularly acute, orders have been placed there for the reconditioning of a number of gun mountings at a cost of about £100,000. About 3,500 additional men are to be taken on at the Dockyards and naval ordnance depots to make good the arrears of work deferred for reasons of economy, and this will cost about £270,000 up to the end of the present month. It is important to notice that the whole of this special expenditure can be met without exceeding the estimates for the current year, owing to the fact that the normal expenditure of a greater amount has been postponed because of the incidence of the boilermakers' dispute. No clearer evidence is surely needed to support the statement that labour is itself the chief sufferer from the strike weapon. Our labour leaders should particularly note the fact, mentioned in the First Lord's statement, that, for the past three years, naval expenditure has been well below the estimates, principally on account of delays to contract work arising from labour disputes, although other less important causes are referred to. The new estimates have been framed on the assumption that such delays will be continued in the coming financial year, but if labour could see its way to profit by the above-mentioned object-lesson, and by avoiding all unnecessary disputes, to increase the rate of progress of naval work, there would be no difficulty in meeting the financial situation which would arise, by means of supplementary estimates.

According to the new estimates, the numbers borne will amount to 100,787, and their pay will absorb a sum of £14,245,000, neither of which figures differs materially from those of the estimates for the current year; the numbers are actually a little lower and the wages a little higher for the ensuring year. The votes for victualling and clothing (£4,258,100), for the medical establishments (£462,500), and for civilians employed on Fleet services (£181,200) are all lower than those for 1923–24. The increase on the vote for wages and the decreases on the remaining votes give a combined reduction of £362,300 on the first four votes. A rather smaller sum has been allowed for the educational services in the new estimates, the vote being £341,800, as compared with £353,000 in last year's estimates. Under this vote is included a small item of £5,500 which is interesting, as it represents the estimated cost of the system of vocational training for which provision was first made in the 1923–24 estimates. The training is intended to improve the prospects of men of the Fleet of obtaining employment on their return to civil life, and is carried out by means of lectures and by classes in ships, naval establishments, and municipal technical colleges; the cost is paid partly by the men themselves and partly out of public funds.

The scientific services in connection with the Navy will absorb a sum of £440,000 in the coming year, which is a little more (£4,200) than the estimate for the current year. Under this heading are included the maintenance of the observatories at Greenwich and at the Cape of Good Hope, as well as that of the Nautical Almanac Office, but the principal expenditure is incurred in connection with the hydrographic services, the Admiralty Compass Department, scientific research and experimental work, and the Mining and Anti-Mining Design Department and Signal School at Portsmouth. Scientific research work and experiments alone account for a total sum of nearly £250,000, made up of salaries, wages, grants, and maintenance of research establishments; other items in the vote are £92,602 for the Mining Department and Signal School, £86,583 for the Hydrographic Department, and £20,927 for the Compass Department. The gross expenditure on the scientific services, it is interesting to note, will be more than three times the figure given in the 1914–15 estimates, after allowing for the present reduced purchasing power of money, and this is a clear indication of the increased importance of science in connection with the warfare of the future.

The cost of the reserves is estimated at £491,500, a reduction of £81,300 on the figure for the current year. The vote for shipbuilding, repairs, maintenance, &c., is divided, as usual, under three headings, of which the first two cover the cost of *personnel* and *matériel* for dockyard work at home and abroad, while the third relates to naval construction work by private contractors. The three items comprising the vote are £7,045,000, £5,397,900 and £5,820,300, respectively, the total amounting to £18,263,200, which is £549,550 more than the corresponding figure for the current year. It is proposed to lay down three of the five new cruisers in the dockyards, the other two being put out to contract, and the programme of dockyard work includes the completion of the cruisers Effingham, Frobisher and Emerald, the flotilla leaders Keppel and Broke, three destroyers and five submarines, as already mentioned. The main item in the vote for dockyard *matériel* is the cost of fuel for the Fleet, which amounts to £3,802,000. For reasons of economy it has been decided, unfortunately as we think, still further to restrict the steaming and fuelling facilities of the Fleet, and to postpone the building up of reserves of oil fuel. In consequence of this policy the expenditure on this item will be £488,000 lower than the estimate for the current year.

The proposed expenditure on contract work shows an increase of £788,850 in comparison with the estimates for 1923–24, the increase being accounted for by work in connection with the five new cruisers and two destroyers. As previously mentioned, three of the former will be laid down in the dockyards, but their machinery armour and ordnance will be constructed by private firms. The most important items under the heading of contract-work are £1,303,000 allowed for the purchase of propelling machinery, £967,000 for hulls, £1,025,000 for armour and £1,695,722 for gun mountings and air compressors. The battleships Nelson and Rodney are, of course, being built by contract, although their progress during the current year has been greatly retarded by the boilermakers' dispute. It is not possible to determine the precise amount allocated for work on these vessels in 1924–25, but it is stated that, in pursuance of the policy outlined above, the provision made for them has been estimated on a very conservative basis. As illustrative of the difficulties with which the private armaments firms have had to contend in post-war times, we may call attention to the fact that the net estimate for contract work in the year 1914–15 amounted to £14,287,800, which would be equivalent

to over £23,000,000 at the present time. The proposed expenditure with private firms in the ensuing year is only about a quarter of the latter figure, although, in most cases, the highly specialised plant required for armaments construction was considerably extended to meet the war demands.

Other items in the estimates are £3,975,000 for naval armaments, which includes the upkeep of the Government naval armament establishments and the purchase of stores, such as guns, projectiles and ammunition, and £3,080,000 for works, buildings and repairs. In the latter are included the sum of £648,600 for the provision of oil-fuel storage, £320,000 for increasing the width of the entrance to No. 5 Basin at Plymouth, and £135,000 for the construction of a berth for a floating dock, also at Plymouth. The remaining votes which make up the grand total of £55,800,000, are £856,000 for miscellaneous expenditure, £1,229,500 for the Admiralty Office, £7,137,800 for non-effective services, and £837,800 for civil superannuation, &c.

The discussion on the Estimates in the House on Tuesday last, turned mainly on the question of the naval base at Singapore, the Government having announced its intention not to proceed further with the scheme. The reason for the decision appears to be that the construction of a new base capable of dealing with the largest capital ships, would have a detrimental effect upon the Government's foreign negotiations. This is difficult to follow, since the proposal was made known at the Washington Conference, was approved at the Imperial Conference, and is generally admitted to be essential from the point of view of naval defence in the Pacific. These points appear to us to outweigh the argument that the objects for the construction of the base might be misunderstood by some foreign power. It is, of course, quite true that, at the present time, there is no actual necessity for a naval base in the Pacific, but such works as those contemplated at Singapore take several years to complete, and during that period the international situation may be greatly modified. In any case, while the Singapore base would threaten no one, its possession would greatly facilitate the problem of the defence of the outlying parts of the Empire and would probably go a long way towards preventing the defence problem from arising in a practical form.

THE MACHINERY FOR THE FIRST DIESEL-DRIVEN PASSENGER LINER, THE "AORANGI."

So many and rapid have been the changes in the nature of the propelling machinery of large passenger liners during the last generation that less startled, perhaps, than might have been expected were the feelings expressed when, more than a year ago, the Union Steamship Company of New Zealand, placed the order with the Fairfield Shipbuilding and Engineering Company, Limited, of Govan, for a large Diesel-driven passenger liner. The main propelling machinery for this ship is now in an advanced state of erection in the engine-builders' works, and the first of the four main engines has now completed a series of comprehensive bench trials. During the last fortnight demonstration trials have been carried out before leading shipowners, shipbuilders, and marine engineers. Up to the present time this is the largest powered marine oil engine to be completed. The ship Aorangi, with four propellers, is designed to give a speed of 18 knots. Each main engine is to develop about 4,000 i.h.p., or a total of 16,000 i.h.p. When this ship goes to sea, which it is hoped will be about the end of the present year, she will be the first Diesel-driven passenger-carrying liner afloat.

The main engines are of the Sulzer, two-stroke cycle, single-acting type, having cylinder dimensions of 27½ in. diameter and 39 in. stroke. The relatively short stroke, or low ratio of stroke to diameter, permits of a speed of revolution in service of about 127 r.p.m., which should give an entirely satisfactory propeller efficiency for this size and speed of vessel. In view of the important duty of this machinery, the standard design of bedplate and columns has been somewhat altered. The bedplate has been considerably stiffened, and is designed to be bolted directly to the tank-top without the introduction of any built-up seating. It was noticed, when running in the shop, that relatively few holding-down bolts were required. Similar conditions were observed with the columns, and although the usual Sulzer configuration has been retained, the columns are not only considerably stiffened by internal ribbing, but are sub-divided to facilitate casting, and the various sections are bolted together internally. Large doors swinging on hinges give access to the crank-cases at both front and back. This free access is made possible by reason of the arrangement of crosshead guides adopted, which is similar to paddle-engine practice, there being four slippers for each main line. Bearing surfaces generally have been increased to reduce pressures and give easy wearing conditions. In accordance with standard two-stroke cycle practice, the pistons are built-up in several sections. In the case of this Fairfield-Sulzer engine, particularly long bolts, providing resilience, serve to connect together the piston-rod forging, the intermediate piece, and the piston crown. The bottom part of the piston, of thin and light section, serves as a shroud to cover the exhaust and scavenging air ports of the cylinder throughout the whole of the piston stroke. To reduce the height of the engine, these pistons dip down at the bottom of the stroke, into the crank-case, between the four guides, which take the alternating side thrusts of the connecting rod. The pistons are cooled with salt water led in and out through the usual telescopic pipes inside the crank-case. It was noticed during the running of the engine that this service was working well, and that there was no visible or audible blow-back past the piston rings.

The cylinder, cylinder-head, and valve-gear design follows well tried-out "Sulzer" practice (see ENGINEERING, vol. cxvi, page 129), with the exception that for the control of the entrance of the scavenging air to the supercharging ports in the main cylinders the earlier type of rotary valve, driven from a weighshaft operated by spiral gearing from the crankshaft, has been eliminated, and a number of multiple automatic-disc valves per cylinder now control the entrance of this air. This forms one of those interesting little improvements by way of simplification, and it is difficult to understand why it was not earlier adopted. Obviously, in this application the automatic valve has very considerable advantages over the positive-operated rotary type, since it only comes into operation when the pressure of the scavenging air in the scavenging-air reservoir definitely exceeds the pressure within the working cylinder. Economy of scavenging air results and in addition the eduction effect of the exhaust is allowed full scope in creating the necessary drop in pressure to facilitate the introduction of scavenging air. The pressure of the scavenging air was observed in the trials to be about 1½ lb. per square inch. It should be recorded that in this ship all the scavenging air will be supplied by rotary blowers driven by electric motors. The power necessary for the operation of these electrically driven blowers will be generated by auxiliary Diesel engines of the same type as the main units. These blowers run at a very high speed of revolution and each is capable of supplying two main engines. During these shop trials half of the output from the blower in operation was bye-passed through a special pipe to the outside of the erecting shop.

At the forward end of each main engine are two injection air compressors, each having three stages, and the output of these machines is so proportioned that there is a very considerable margin—in fact, to the extent that either of the two compressors can supply the main engines with sufficient blast air to maintain approximately full speed. These compressors are of the differential-piston, three-stage, trunk-piston type with long connecting rods. The valves are rendered accessible by carrying them in easily withdrawable plugs. The injection-air bottles are mounted above the compressors. The main engines are manœuvred from the top platform at the forward end. In this position the various operations of starting, stopping, or reversing can be carried out with the interposition between the control levers and the actual shafts, valves, &c., to be operated, of the minimum intermediate mechanism. Moreover, the control of the blast air during the manœuvring of an air-injection Diesel engine is probably the most important item, and in this location, forward on the top platform, the operator is adjacent to the injection compressors and to the blast bottles with their valves. The rotation of a hand wheel sets the engine valve gear for ahead or astern running. The operation of a small air twin-cylinder servo-motor sets the engine-valve gear successively in the positions "six cylinders on air," "three cylinders on air and three cylinders on fuel," and finally, "six cylinders on fuel." It is interesting to note that this air servo-motor is an exact duplicate of the one which turns the main engines through gearing. The operation of this valve-gear servo-motor on trial was very efficient and quite "dead-beat" in action. The fuel lever controls the suction valves of the six fuel-injection pumps driven from one eccentric, level with the engine top platform, on the vertical shaft at the after end of the engine. This vertical shaft through spiral gearing drives the camshaft from the crank-shaft, and its location at the after end of the engine ensures absence of chatterinig of the teeth, due to torsional vibrations or oscillations in the main crankshaft.

TABLE OF TRIAL RESULTS WITH FAIRFIELD-SULZER MARINE OIL ENGINE.

Load.	Duration of trial.	Mean Indicated Pressure lb. per sq. in.	Revs. per minute.	I.h.p.	B.h.p.	Efficiency per cent.	Fuel, lb. per b.h.p. per hour.	Pressures, lb. per sq. inch.		Fuel.	
								Injection Air.	Scavenging Air.	Gal. Values Gross B.T.U.'s	Specific Gravity.
Three-quarters	1 hour.	74·2	114	2,967	2,360	79·5	0·373	840	1·13	19,710	0·879
Full	72 hours.	88·1	126·8	3,915	3,220	82·2	0·392	932	1·85	19,710	0·879
12 per cent. overload	12 hours.	94·1	131	4,321	3,552	82·1	0·412	975	1·92	19,710	0·879
20 per cent. overspeed	2 hours.	89·1	152	4,750	3,800	80·0	0·43	980	1·91	19,710	0·879

For a ship of this size, where there are four main engines and the large number of auxiliaries required in passenger-carrying service, there are always sufficient engineers in the engine-room to ensure a good watch being kept over the important pumps, auxiliaries, valves, main engine piston-cooling service, &c., on the bottom platform, so that the position of the manœuvring controls of the main engine on the top platform would seem to be an excellent arrangement, and is likely to be adopted quite generally in future Diesel ships of this power and size, especially if the camshaft is at the cylinder-top level. It will not readily be conceded, however, that for the average single-screw cargo boat top-platform control would adequately meet the case, owing to the limited personnel available and the number of important duties which can only be attended to from the engine-room floor.

Bench trials have been carried out at varying powers and speeds of revolution, using a good quality of Diesel fuel oil of a gross calorific value of 19,710 B.Th.U. and a specific gravity of 0·879. Tests with a number of different grades of fuel oil are, it is understood, being proceeded with. The table above gives the results of the trials which have been carried out, from which it will be noted that a 12 hours' overload trial was successfully accomplished at a speed of 131 r.p.m., when indicating in the cylinders a mean pressure of 94·1 lb. per square inch with a fuel consumption of 0·412 lb. per brake horse-power per hour. When considering these results full cognisance must be taken of the fact that the scavenging air was supplied by a separate auxiliary, and therefore the power required to drive it and the fuel necessary for the generation of such power must be added to this fuel

consumption, in order to make comparisons with other engines. The consumptions on overload, of course, are not necessarily the best that can be achieved at these particular powers, since the timing of the engine, the type of pulveriser adopted, and other details were chosen to give the maximum economy at the normal full power, 3,220 b.h.p., which is developed at about 127 revolutions.

We were privileged to witness the manœuvring trials of this engine carried out in the shop, although, of course, there was no load on the engine. It was observed that the engine could be handled in that sure and speedy manner which has come to be expected as characteristic of the modern marine Diesel engine. Reversal from full speed ahead to full speed astern was carried out in less than 10 seconds, and certainly in less time than would be demanded in a well-handled ship. While manœuvring, due to absence of load, the engine reached a maximum speed of over 150 r.p.m., approximately the same speed as during the 20 per cent. over-speed trial, when it was observed, as regards steadiness, that there was little difference between the conditions at this speed and the normal. It should be pointed out that for 152 r.p.m. the piston speed works out at approximately 990 ft. per minute. Throughout all these trials the running of the engine in regard to lack of vibration was al]that could be desired. It is not possible to make a definite statement on the silence of running because of the temporary nature of the large piping for the exhaust and scavenging air used in the tests. The ring in the exhaust pipe and the whistle of the scavenging air were the cause of more noise than the operation of the mechanical parts of the engine. The impression gained from observation of the running of this engine was most favourable. The finish could not have been better, and the whole appearance suggested a first-class machine.

It is understood that, given reliable operation of the main propelling units, the low Diesel-engine consumption ensures that the economy of operation of this ship will be a compelling advantage. Bench trials can never be an absolute indication of behaviour under average sea-going conditions, yet until the trials ashore against a measured load have clearly demonstrated the efficiency and reliability of operation of a new prime mover to the fullest extent possible, confidence will not be established.

The necessity in the past for high powers, particularly in the early stages of the application of the steam turbine to mercantile marine work and to naval propulsion, have accustomed the shipowner to more than two shafts. The disadvantages of this arrangement are not great, so that no fears need arise on this account. The performance of the machinery of the Aorangi at sea will be watched with intense interest. Probably it can be said with truth that, in the past, British enterprise with the marine internal-combustion engine has not been in the forefront. Therefore it is with more than usual gratification and pride that we may reflect that the first internal-combustion engined passenger liner of large size and of high power will be delivered to British owners from a famous Clyde yard.

INDUSTRIAL NOTES.

In our last issue we gave an outline of the miners' wages claim. The offer made by the Mining Association to the Miners' Federation is, briefly, as follows:—(1) Standard profits to consist of 15 per cent. of standard wages, instead of 17 per cent. as at present. The surplus remaining after deduction from proceeds of the cost of standard wages, costs other than wages and standard profits, to be divided between wages and profits in the proportion of 87 per cent. to wages and 13 per cent. to profits, instead of the present figures of 83 per cent. and 17 per cent. respectively. (2) The general minimum percentage in standard wages to be increased from 20 to 30 above the wages of 1914. (3) In no district shall the wages of any adult able-bodied day-wage workman fall below a figure of 40 per cent. above the standard wages, as defined in Clause 7 of the Wages Agreement, of the lowest paid class of day-wage workman in the district. (4) Subsistence wages shall be paid in the areas in which they have been, or may in future be, fixed by the District Board. (5) There shall be effective recoupment of deficiencies below standard profits, but only one-half of any future surplus available for this purpose in any one ascertainment shall be so applied, and the remaining half shall be divided between wages and profits in the agreed proportions, any balance of the deficiency being again carried forward.

The delegates of the Miners' Federation met in London last Friday to consider the owners' terms as given in the foregoing. At the close, the chairman stated that the Executive Committee had very carefully examined the whole situation and had come to the conclusion to advise the conference to pass the following resolution:—"This conference, having regard to the inadequacy of the terms offered by the coal-owners, cannot advise their acceptance by the workmen. We therefore urge upon the Government to pass the Minimum Wage Bill to secure for the miners a wage commensurate with the cost of living. It is further decided that this conference stands adjourned until March 26." The resolution was carried unanimously.

Mr. Evan Williams, president of the Mining Association, has stated that he greatly regretted the decision taken by the miners' executive, and believed it was not arrived at upon the merits of the terms, but because of the hope that through the influence of Parliament something more might be imposed on the industry. The owners' terms constituted, he declared, the utmost limit to which they could go. The view on which the miners' case was founded was that the price of coal could be increased to any extent necessary to pay whatever wages they demand. The owners viewed with great apprehension any increase in the price to the home trade, and regarded any increase on export coal as impossible under the present world conditions. Their offer was more advantageous to the lower paid classes than the miners had demanded. They were convinced that the offer would stand any examination to which it might be subjected. To attempt to deal with the question by legislation would inevitably make negotiations between owners and miners themselves impossible, would delay settlement, and invoke the whole industry in chaos.

The Mines Department last Saturday stated that after the conference of the Miners' Federation the Secretary for Mines, Mr. Shinwell, interviewed representatives of the owners and of the miners separately, and, following these interviews, he asked both sides to meet him again. This meeting took place yesterday, and we shall report further in our next issue.

The carmen and motormen employed in the depots of the London, Midland and Scottish Railway, who had come out on strike to the number of several thousands, decided to resume work last Monday, following upon the company's statement that their grievances would be looked into.

The unauthorised strike of Southampton shipyard workers remains unsettled, and continues to cause anxiety to the shipbuilding firms in general and to the unions which are affiliated to the Federation of Engineering and Shipbuilding Trades. Since our last issue meetings have taken place every day to deal with the situation, but without effect so far. Should the Southampton men remain obdurate, the shipbuilding firms have announced that they would be compelled to declare a national lock-out. A meeting of the Federation of Trades and employers, however, takes place to-day, at which it is hoped a settlement of the difficulty may be reached. At the time of going to press, however, the chances of a settlement appear very remote.

The Ministry of Labour state that after the settlement of the railway dispute, on January 29, employment quickly recovered from the decline caused by the shortage of transport, and there was a further and continuous improvement during February. Among workpeople insured under the Unemployment Insurance Acts in Great Britain and Northern Ireland the percentage unemployed on February 25 was 10·7, compared with 11·9 on January 28 (the last full day of the railway stoppage) and with 10·7 on December 21, 1923; on February 26, 1923, the corresponding percentage was 12·2. Among members of trade unions from which returns were received the percentage unemployed was 8·6 at the end of February, 1924, compared with 8·9 at the end of January, 1924. The total number of workpeople on the live registers of the Employment exchanges on February 25 in Great Britain and Northern Ireland was approximately 1,156,000, of whom 858,000 were men and 227,000 were women, the remainder being boys and girls; on January 21 (the first day of the railway stoppage) the total was 1,253,000, of whom 925,000 were men and 248,000 were women. Employment was good in the coal-mining industry and in the tinplate, steel sheet, carpet, jute, and coach-building trades; it was fairly good with skilled operatives (except painters) in the building trades, with millsawyers, and in certain sections of the metal trades. In most of the other large industries it was still slack or bad.

In the industries for which statistics are available the changes in rates of wages reported as having taken effect in February resulted in an aggregate increase of nearly 90,000*l.* in the weekly full-time wages of 640,000 workpeople, and in a decrease of 3,250*l.* in those of nearly 100,000 workpeople. Building trade operatives in most districts in Great Britain received increases, under a cost-of-living sliding scale, of ½*d.* per hour in the case of craftsmen and of ¼*d.* or ½*d.* per hour in the case of labourers, and there were additional increases of ½*d.* or 1*d.* per hour in a number of towns in the midland, southern, and south-western counties. Dock labourers at all the principal ports had their wages increased by 1*s.* per day or 6*d.* per half-day in the case of time-workers, and generally by 5 per cent. on the rates operative in August, 1921, in the case of piece-workers. Other important groups of workpeople whose wages were increased included iron miners in Cumberland, steel-sheet millmen, men employed by electrical contractors, leather-belt makers, warehousemen at Liverpool, and workpeople employed in the non-trading services of various local authorities in Yorkshire. The principal decrease in wages affected steel smelters and millmen in various districts in England and Scotland, whose wages were reduced by 1¼ per cent. on standard rates (equivalent to about 1 per cent. on current rates). Other groups of workpeople whose wages were reduced included subsidiary workers in the iron and steel trade in various districts, coal miners in the Radstock district, ironstone miners and blast-furnace workers in North Lincolnshire, and blast-furnace workers in the west of Scotland. There was also a decrease, under the Trade Boards Acts, in the minimum rates fixed for men employed in the chain-making trade. During the first two months of 1924 the changes in rates of wages reported to the Labour Department have resulted in a net increase of nearly 180,000*l.* in the weekly full-time wages of over 1,600,000 workpeople and in a net reduction of 28,500*l.* in the wages of 580,000 workpeople. In the corresponding period of 1923 there was a net reduction of over 120,000*l.* in the weekly full-time wages of about 950,000 workpeople and a net increase of 43,000*l.* in the weekly wages of 670,000 workpeople.

On March 1 the average level of retail prices of the commodities taken into account in the statistics prepared by the Ministry of Labour (including food, rent, clothing, fuel, light, and miscellaneous items) was approximately 78 per cent. above that of July, 1914, as compared with 79 per cent. a month ago and 76 per cent. a year ago. For food alone the corresponding percentage for March 1 was 76, as compared with 77 a month ago and 71 a year ago.

The number of trade disputes involving stoppages of work, reported to the Department as beginning in February, was 56. In addition, 20 disputes, which began before February, were still in progress at the beginning of the month. The total number of workpeople involved in all disputes in February was approximately 144,000, as compared with 83,000 in the previous month and 37,000 in February, 1923. The estimated aggregate duration of all disputes during February was about 700,000 working days, as compared with 629,000 days in January, and with 325,000 days in February, 1923. The principal dispute was that involving dock workers throughout Great Britain, which was in progress from February 18 to 25.

THE INSTITUTION OF PETROLEUM TECHNOLOGISTS.—At the sixth annual dinner, held last Tuesday in the Connaught Rooms, under the presidency of Mr. H. Barringer, M.Inst.C.E., Engineer-Admiral Sir Robert Dixon, replying to the toast of the Services, proposed by Professor J. S. S. Brame, said that the Navy was criticised for the criminal waste of burning oil under boilers and for taking a lukewarm interest in oil engines. While all warships had a speed of 21 knots and a good many of over 30 knots, only 25 mercantile ships in the world—apart from cross-channel boats—steamed at over 20 knots. High speeds meant heavy engines; but engine weights ranged from 250 lb. to 350 lb. per shaft horse-power on motor-ships, against 80 lb. on battle cruisers and 33 lb. on destroyers fitted with steam installation, and the weight of the machinery on a motor-ship of 3,000 h.p. was equal to that of a 27,000-h.p. destroyer. Advance in speed might be made by a change of type. Sir Westcott Abell, in proposing the toast of the "Petroleum Industry," mentioned that the figures for the total tonnage built had been the same in 1922 and in 1923 viz., about 2½ million, whilst, however, one-eighth of that—*i.e.*, 300,000 tons—had been in motor-ships in 1922, such vessels had represented one-fourth of the total in 1923, and since 1913 the tonnage of motor-ships built had increased by 250 per cent. The President announced that the Standardising Committee of the Institution had finished its inquiry and was issuing a report, and that the Universities of Birmingham and London were now offering facilities for students of petroleum technology.

SHOCK-ABSORBING AND CONCENTRIC SPEED TRANSFORMER.

IN engineering practice examples of power transmission are commonly found in which the drive must not only be given through a speed-reduction gear, in order that the power unit and the plant to be operated may both be run at suitable economic speeds, but also where the driving and driven shafts must be in line. To meet these conditions in a gear system and to ensure easy starting and freedom from other shock-producing actions, must be regarded as no mean achievement, but that all these requirements can be met in a very satisfactory and efficient way was demonstrated to us recently by an example in which machinery for treating rubber had to be driven from an electric motor. The gear in use was designed by Messrs. Bostock and Bramley, of Netherton, Huddersfield and constructed by Messrs. Joshua Buckton, and Company, Limited, of Well House Foundry, Leeds. The system in use combined the speed reduction obtainable with an epicyclic gear, with the use of the shock-absorbing characteristics of helical springs. This speed transformer is illustrated on this page by sections of the actual equipment, and by a series of reproductions from photographs on the opposite page.

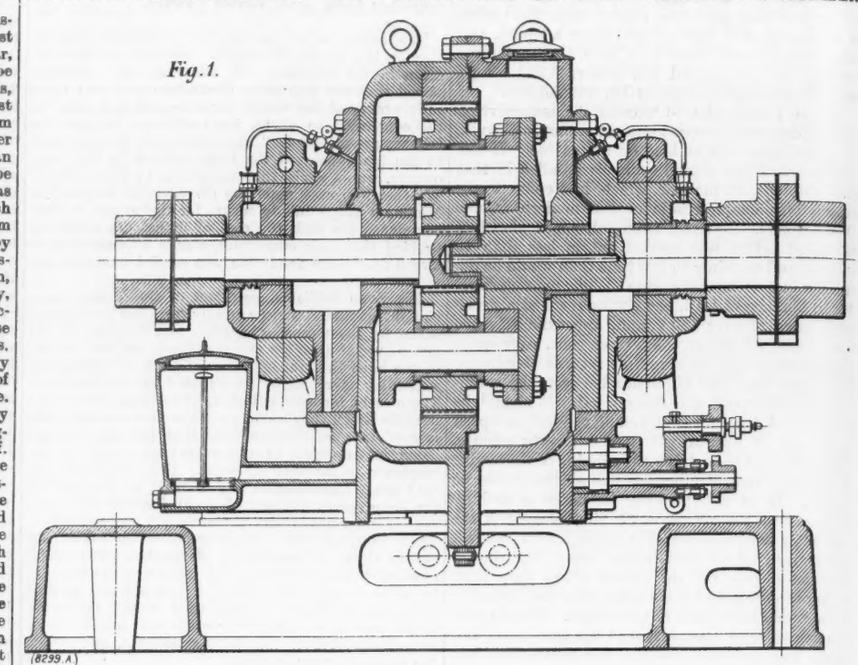
The manner in which the gear is arranged is clearly indicated in Figs. 1 and 2. On the end of the driving-shaft there is a sun pinion, solid with the shaft itself. The planet gears are four in number and engage on the inside with the teeth of the sun pinion and on the outside with an internal gear ring rigidly secured to the casing. The spindles for the planet gears are carried by a solid casting which is bolted to a disc on the driven shaft. The casting provides support to both ends of the spindles, the two parts being connected by four solid arms of triangular cross-section, the positions of which are shown in Fig. 2. It will be noticed that the casting supporting the spindles at the driving end of the system encircles a part of the main casing and runs freely on a bush. The arrangement is very compact and, as will be observed in Fig. 1, the end of the driven shaft is reduced to permit it to enter the bored end of the driving shaft, from which it is separated by a simple bush. The whole system is erected within a casing which is not mounted rigidly on the bedplate but is supported in trunnions and free to turn only to a definitely limited extent against the action of two long helical springs provided below the gear casing. Were no provision made to prevent the complete rotation of the casing, no motion would be carried through to the second shaft, but the introduction of the shock-absorbing device as an intermediate connection between the casing and the bedplate makes the transmission possible and causes all sudden applications of load to be met without jar and without pulling up the power plant. All the heavy stresses during the fluctuation of the load are thus prevented from falling upon the teeth, and consequently the gear is saved much wear and tear. The anchoring system for the casing is easily understood from Fig. 2, in which are seen the bolts extending between the two sides of the bedplate, on which the springs are mounted. A chain connects the casing with a slide on the bolts, which is drawn against the springs. Any fluctuation of the load causes a slight turning of the casing against the action of the springs, which varies in magnitude with the change in conditions and continues until equilibrium is established, and thus variations in load are accompanied by oscillations of the casing. In the action of starting against a heavy load, such as that found with the machinery for treating rubber, the casing is turned quite markedly and the motor is enabled to take its load without any of the usual signs of shock.

The lubrication of the whole system is entirely automatic and works continuously. The oil is forced under pressure to all main and planet shaft bearings and to the teeth of the wheels. The pump for the system, seen in the lower right-hand side of the section in Fig. 1, is driven from the main shaft, and is situated below it. It is of the gear type, and the oil it circulates is continuously filtered, the filling chamber being provided with a filter at the bottom through which the oil is drawn. This filter can be removed for cleaning at any time, and actually while the gears are in motion.

A complete electric motor-driven equipment is seen in Fig. 3, while the gear casing is shown removed in Fig. 4, and the bedplate with the springs in place and the chain ready for attachment to the casing is depicted in Fig. 5. The two other illustrations, Figs. 6 and 7, show the features of the mounting of the planetary system. The gears and their arrangement may, of course, be designed to give a very large or only a small reduction to suit the circumstances of the drive, and equipments have already been fitted to a number of different transmission systems, where speed reduction and the freedom from the shock due to suddenly applied loads are imperative requirements, such as in hydraulic machinery, hoists, drop hammers and rolling mills.

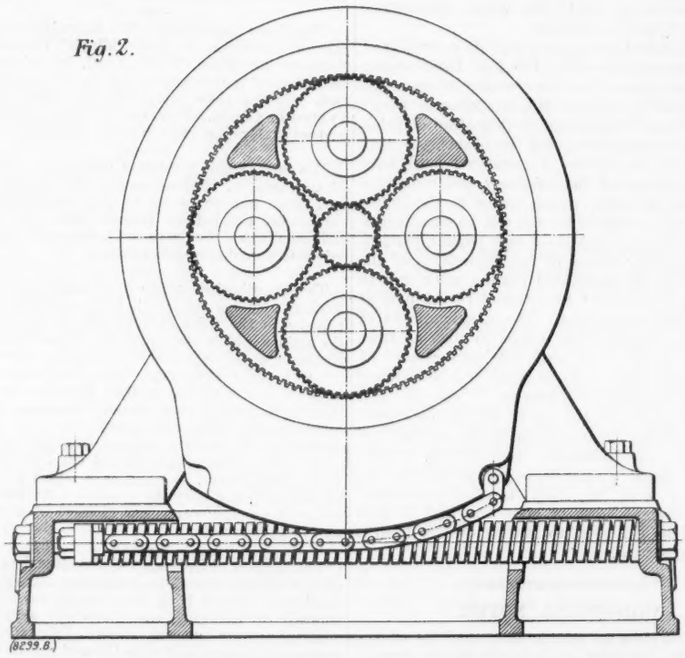
SHOCK-ABSORBING CONCENTRIC SPEED TRANSFORMER.

Fig. 1.



(8299.A)

Fig. 2.



(8299.B)

THEORY OF TRANSVERSE OSCILLATIONS IN GIRDERS AND ITS RELATION TO LIVE-LOAD AND IMPACT ALLOWANCES.*

By Professor CHARLES EDWARD INGLIS, O.B.E., M.A., M.Inst.C.E.

THE object of this paper is to throw some light on the rather obscure phenomena attending the behaviour of girders under the influence of dynamical loads, and, incidentally, to bring out by methods of mathematical analysis the main considerations to be taken into account in composing rational formulas for live-load and impact allowances. These allowances have been the subject of a great mass of practical research, but the absence of any rational theory to guide the experiments has been apparent in much of this work. For a more comprehensive and intelligent study of the problem it is necessary for mathematical and experimental research to co-operate until they come into harmonious agreement. Predictions based purely on mathematical deduction carry no conviction, and formulas deduced by experiment, if unconfirmed by mathematical reasoning, ought to have no permanent place in the science of engineering.

Throughout the paper the term "live load" is confined to the dynamical effect produced by a load of constant magnitude, by reason of its movement along or across a girder. The term "impact" refers to the dynamical effect produced by a force, by reason of its change in magnitude.

For a girder freely supported at its ends, the deflection or oscillations produced by statical or dynamical distributions of load can be most conveniently studied by the methods of harmonical analysis, and the simplicity and elegance of the results obtained thereby is a clear indication that Nature intended such problems to be handled in this manner. Thus if a girder of length l, freely supported at its ends, carries a load-distribution defined by $p = p_0 \sin(\pi x/l)$, the corresponding deflection is defined by $y = (p_0 l^4/\pi^4 EI) \sin(\pi x/l)$. A sinusoidal distribution of load produces a sinusoidal deflection, and this harmonious relationship provides a most powerful method for the determination of deflections.

Any form of continuous load-distribution and any system of concentrated loads can be analysed into a

* Abstract of a paper read before the Institution of Civil Engineers on Tuesday, March 18.

SHOCK-ABSORBING AND CONCENTRIC SPEED TRANSFORMER.

(*For Description, see opposite Page.*)

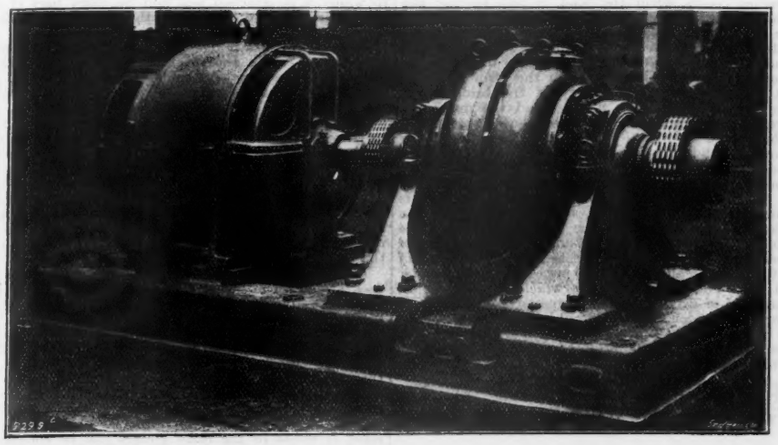


FIG. 3. COMPLETE MOTOR-DRIVEN SPEED TRANSFORMER.

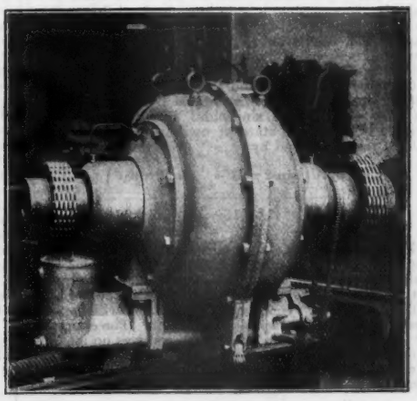


FIG. 4. THE FLOATING GEAR SYSTEM REMOVED.

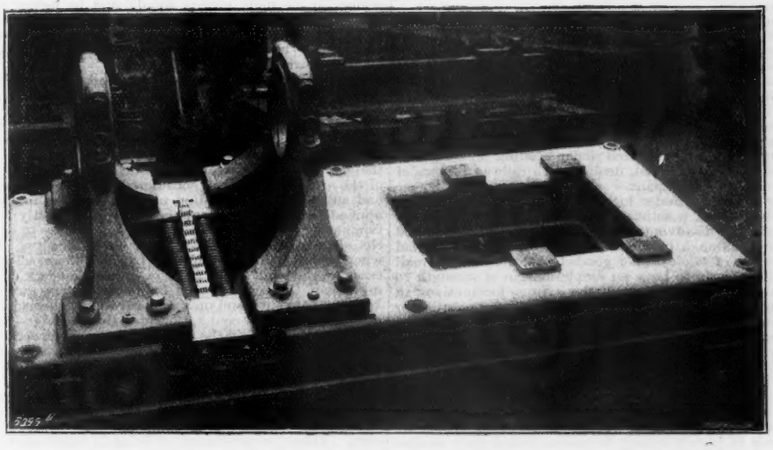


FIG. 5. BEDPLATE SHOWING TRUNNIONS AND SHOCK-ABSORBER.

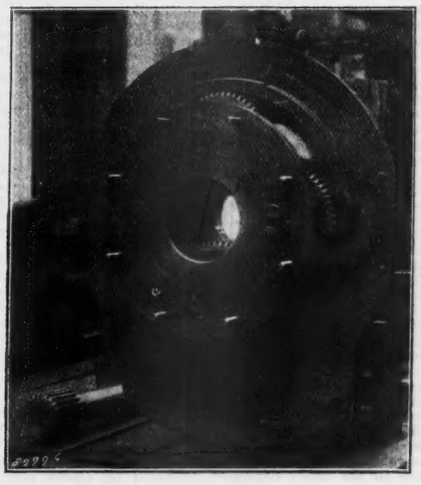


FIG. 6. THE GEAR INTRODUCED INTO CASING.

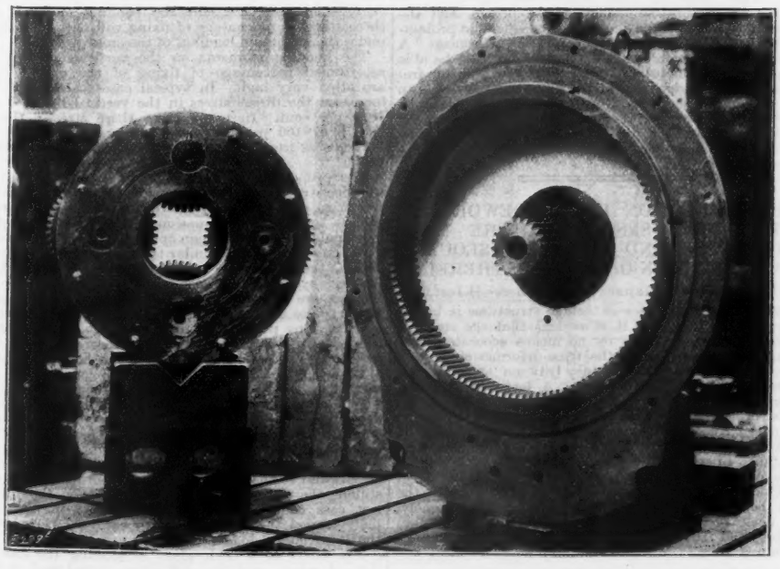


FIG. 7. THE SEPARATED COMPONENTS OF THE GEAR.

system of sinusoidal load-distributions. Each of these distributions gives rise to a corresponding sinusoidal deflection, and the resulting deformation is thereby conveniently expressed in the form of a series which is rapidly convergent, and in consequence, particularly well adapted for arithmetical computations.

If the deflection at the centre of the girder is required the second harmonic component makes no contribution, and the third harmonic component is usually so small that for practical purposes it can be ignored. Thus, if a load P is applied at a point distant a from one end of the girder, the central deflection is given to an excellent degree of accuracy by $(2l^3/\pi^4 EI)\sin(\pi a/l)$. Although, throughout this paper methods of harmonical analysis are extensively employed, the finite solution from which the series emanates is laid down in every case. Harmonic series are subject to certain limitations in the matter of differentiation, but these difficulties disappear if the true summation of the series is obtained in a finite form.

The oscillations of a girder produced by moving and pulsating loads are determined by solving a differential equation which has the general form

$$EI\frac{d^4y}{dx^4} + m\frac{d^2y}{dt^2} = f(x,t),$$

where m is the mass of the girder per unit length and $f(x, t)$ is an expression for the applied load-distribution, which in general is a function of both x and t. The solution of the differential equation with the right-hand side made zero, gives the state of free oscillation of the girder, and from this its natural frequencies can be obtained. In all calculations relating to oscillations set up in a girder a knowledge of its natural frequency is essential; and, if this information is forthcoming dynamical oscillations can be calculated with as much accuracy as statical deflections. The natural frequency of a girder sets the scale by which it is possible to judge whether an action is to be regarded as sudden or sluggish,

and it also defines the conditions under which periodic forces may develop harmful synchronous oscillations.

Most practical problems relating to the oscillations of girders refer to cases in which the oscillations start from a state of rest. Any particular solution of the fundamental differential equation does not usually conform to this starting-condition, and an adjustment has to be made by superposing a solution obtained by making the right-hand side of the equation zero. Thus in general the oscillation which satisfies the starting-condition may be viewed as the superposition of two oscillations of different frequencies which are referred to as the forced oscillation and the free oscillation.

If the load-distribution is defined by $p = p_1 \sin 2\pi nt \sin(\pi x/l)$, *i.e.*, if it is sinusoidal in distribution and periodic in time, the state of oscillation set up from a state of rest is defined by

$$y = \frac{p_1 l^4 \left(\sin 2\pi nt - \frac{n}{n_0}\sin 2\pi n_0 t\right)}{\pi^4 \mathrm{EI}\left(1 - \frac{n^2}{n_0^2}\right)} \sin\frac{\pi x}{l},$$

and at the worst the dynamical character of the load magnifies the corresponding statical deflection by a multiplier $(n_0/n_0 - n)$ where n_0 is the natural frequency of the girder and n is the frequency of the applied load.

The case of a synchronous oscillation which occurs when $n = n_0$ calls for special treatment. The expression for the oscillation given above then conveys no meaning, since it contains both a zero numerator and denominator. It can be shown, however, that this indeterminate form is really the same as

$$y = \frac{p_1 l^4}{2\pi^4 \mathrm{E\,I}} (\sin 2\pi n_0 t - 2\pi n_0 t \cos 2\pi n_0 t) \sin\frac{\pi x}{l}$$

The second term inside the bracket constitutes the element of danger in a synchronous oscillation. It indicates a steady growth in the amplitude of the oscillation, and after a time t the dynamical magnification is approximately $\pi n_0 t$. The allowance which has to be made to deal with a synchronous oscillation accordingly depends upon the length of time the synchronous forces persist in their action.

The dynamical effect of a uniformly-distributed load which fluctuates periodically can be treated by the method of harmonical analysis, though an alternative solution in a finite form is also given in the paper. The results obtained are applied to study the dynamical effect of a gust of wind striking a bridge. Even in the extreme case in which the gust of wind rises to its maximum and falls again to zero in a period of 1 second, in comparison with the natural period of oscillation of the bridge for sideways oscillations, this period is so long that the dynamical magnification of the steady load deflection is practically nil.

The oscillations produced by a stationary pulsating force next receive consideration. A solution of the general differential equation is obtained in a finite form and then expanded into a Fourier series for purposes of computation. It again appears that at the worst the dynamical magnification is $n_0/(n_0 - n)$. For the case of synchronism ($n = n_0$) the magnification depends upon the duration of the applied force.

A general expression for the live-load allowance for the cross girder of a single-track railway-bridge is then deduced. If T is the time taken for an axle-load to pass from one cross girder to the next, and if n_0 is the natural frequency of the cross girder, the greatest increment to the crawl deflection predicted by theory is $27/N_0T$ per cent. For a particular case a diagram is drawn which illustrates the oscillation set up at the centre of a cross girder, due to the passage of a single constant axle load. This theoretical result is compared with a similar curve obtained by direct experiment, and a remarkably close agreement is revealed.

The dynamic effect on the same cross girder arising from the impact of balance-weights is considered. If the driving-wheels make N revolutions per second, and in consequence the rail pressure fluctuates between the limits $P \pm R$, the greatest increment to the crawl deflection is approximately $70\,R \Big/ \left(1 - \frac{N^2}{n_0^2}\right) P$ per cent.

For the extreme case in which $R = P$, a diagram is constructed depicting the oscillation at the centre of the cross girder. In this diagram live load and impact effects are both included, and the combined allowance represents an increase of about 74 per cent. on the crawl deflection for the single axle-load. A method of taking into account the mass effects of the moving loads is investigated, and it is shown that the formulas already evolved can take account of this effect if the natural frequency of the cross beam ceases to be regarded as a constant.

The remainder of the paper deals with the oscillations produced in the main girders of a bridge due to the passage of steady and pulsating loads. Solutions are obtained in a finite form and then expanded into a Fourier series to facilitate computation. For a force of constant magnitude moving with velocity v along a girder of length l having a natural frequency n_0, it is shown that the ratio of the maximum dynamical deflection to the maximum crawl deflection is $(1 + v/2n_0l) : 1$.

For a succession of moving loads the state of oscillation set up depends to a great extent upon the spacing of the loads. The case of a 60-ft. span is considered. If the speed is 120 ft. per second and four loads at intervals of 12 ft. cross the bridge, the live-load allowance prescribed by theory is 8 per cent., and for this case the 12-ft. spacing sets up the worst possible oscillation. On the other hand, if the load-interval is 6 ft., the dynamical and crawl deflections are practically identical.

The case of a uniformly-distributed load advancing at a uniform speed across a bridge is then considered, and it appears that in this case the dynamical deflection, even at high speeds, is indistinguishable from the crawl deflection. The impact effects produced by a pulsating load moving along a girder are investigated, particular attention being given to the case in which the frequency of the pulsation coincides with the fundamental frequency of the bridge. For this case the maximum oscillation occurs when the load is just leaving the bridge, and depends upon the number of impulses which occur during the passage of the load. If the driving-wheels of a locomotive are making n revolutions per second, the additions to the rail pressure owing to the balance weights may be written in the form P_1n^2. If n_0 is the fundamental frequency of the bridge, synchronism will occur when $n = n_0$, and the maximum central deflection set up is given by the comparatively simple formula $2n_0^2N(2P_1l^3/\pi^4\mathrm{EI})$, where N is the number of impacts made by the balance-weights as the load crosses the bridge.

The case of a particular class of locomotive and train-load crossing a single-track bridge of 120 ft. span is considered, the speed being such that synchronous oscillations are set up by the balance-weights. The formula given above prescribes an impact allowance of 84 per cent. if the driving-wheels have a diameter of 4 ft. 9 in., and an allowance of 56 per cent. if the diameter is 6 ft. 6 in. The Pencoyd formula, which takes no account of diameter of driving-wheels, suggests an allowance of 71 per cent. in each case. For rail-bearers and for short-span bridges whose natural frequency is too high for synchronism, the greatest addition to the central deflection due to impact is—

$$\frac{P_1 n^2 l^3}{\pi^4 \mathrm{EI}} \left\{\frac{1}{1 - \frac{n}{n_0}\left(1 + \frac{1}{2N}\right)} + \frac{1}{1 + \frac{n}{n_0}\left(1 - \frac{1}{2N}\right)}\right\}.$$

A numerical example dealing with a particular locomotive traversing a 60-ft. span bridge is worked out, and a combined live load and impact allowance, amounting to an addition of about 47 per cent. to the crawl deflection, is deduced.

How far the theoretical formula given above corresponds to reality can only be decided by actual experiments, but theory can hardly be in error in prescribing the ingredients which should be embodied in a rational impact formula, and theory prescribes that the following circumstances at least should be taken into account: (1) The length of the bridge; (2) the natural frequency of the bridge; (3) the fluctuation in rail pressure due to balance-weights; (4) the size of the driving-wheels. To supply information required under heading (2) a systematic research is required, dealing with railway-bridges of various types and spans.

For a three-cylinder locomotive, with cranks spaced 120 deg. apart, a satisfactory balance can be obtained without the disadvantage of varying rail pressure, and for this reason a bridge which has successfully carried the traffic of two-cylinder goods-locomotives with small wheels is likely to have an ample margin of strength to withstand modern three-cylinder express locomotives, in which freedom from impact more than compensates for the increase in dead weight. Impact formulas of the Pencoyd type give no rebate for excellence of balance. For spans of 100 ft. and upwards they would appear to be in fair agreement with theory, provided that the wheels are about 5 ft. in diameter and the locomotive is of the two-cylinder variety. For locomotives of the three-cylinder type and for short-span bridges formulas of the Pencoyd description call for impact allowances which are difficult to justify by any argument based upon mathematical theory.

In conclusion, consideration is given to the mass effect of the non-spring-borne part of the locomotive and train load. This unsprung load must have the effect of varying the natural frequency of the bridge, and the variation of frequency is likely to be beneficial in protecting bridges from the worst effects of synchronism. A pulsating force which is strictly periodic will not be able to remain continuously in step with the varying frequency of the bridge, and in the process of getting into and out of phase periods of large oscillation will be separated by periods of comparative quiescence. If breaks in synchronism did not occur, the impact effects in the case of a double-headed train might occasionally be very severe.

THE INTERACTION IN BRIDGEWORK OF THE DECK SYSTEM ON THE MAIN GIRDERS AND THE CONSEQUENT MODIFICATION OF STRESSES THEREIN.*

By DOUGLAS HENRY REMFRY, B.Eng., Assoc.M.Inst.C.E.

THE theory of stresses in bridge structures is by no means satisfactory, and it is evident that the stresses, as usually computed, are by no means accurate. The secondary stresses due to the truss-deformation do not account for the whole discrepancy between "calculated" stresses and "actual" stresses. A large part of the difference is often due to the interaction of one part of the structure upon another. It is now realised that in a modern riveted truss there is a hitherto disregarded source of strength which, it is believed, increases its resistance to stresses by at least 15 per cent. There is, however, in certain structures another factor, the effect of which, although known to exist, has rarely in the past been taken into serious consideration, namely, the deck system and its interaction upon the main girders and the consequent modification of stresses therein.

* Abstract of a paper read before the Institution of Civil Engineers on Tuesday, March 18.

Study of the subject leads to the conclusion that whenever a deck system is used in a bridge structure it will assist in resisting some of the longitudinal and other stresses which otherwise would have to be resisted entirely by the booms of the main girders. In whatever way the deck system is connected to the main girders, it must afford some assistance to the booms to which it is attached and help to carry part of the longitudinal stresses which, in the absence of a deck, would have to be carried by those booms alone.

In a "through" bridge in which the deck system is attached to, or in the neighbourhood of, the bottom booms, when a live load comes on to the bridge, the elongation of the bottom boom is transmitted more or less directly to the deck system also. Even in the loosest deck system considerable resistance is offered to these forces. This, in the worst cases, may be due to the frictional resistance offered by the parts to movement on each other. Generally such riveting as there is will add further assistance, causing the longitudinal members of the deck to resist considerable tensile stresses. In modern structures a much more solid deck is now favoured than was used in the past, and in a well-riveted deck system the "flange" action developed by the deck system is surprising.

In the case of a "deck" bridge—or one in which the deck system is attached either above, between or just below the top booms of the main girders—the longitudinal stresses in these parts are compressions. The deck system will assist in resisting part of the longitudinal compression which, in the absence of a deck system, would be thrown altogether upon, and be resisted by, the top booms alone.

One object of this paper is to indicate the approximate relief which the action of the deck system may afford to the booms of the main girders. Before, however, relief of stress in the main girders can be considered, the question arises whether the effect of the deck system is to increase the stresses in any part. If the deck system comprises rail-bearers or stringers carried by cross girders, the effect of the attachment of the cross girders to the main girders should first be looked into. In cases where the ends of the cross girders are fixed and riveted to the web members of the main girders, very heavy bending stresses may be induced in such members owing to the attachment.

Where the cross girders are attached to the vertical members in the main girder webs, it is comparatively easy to approximate to the percentage of fixing of the ends of the cross girders. The method employed is to calculate the slope of the end of the cross girder when considered as simply supported, and then to calculate the slope of the vertical at a point opposite the centre of the cross girder, when considered as simply supported and subjected to a bending moment such as would be applied thereto if the cross girder were perfectly fixed. Comparing these two limiting slopes, it is easy to decide the slope which would be taken up by the two parts when equilibrium is established between them. Typical cases worked out show that in a deep modern 100-ft. deck span, the percentage of fixing of the cross girders is 26 to 28 per cent., and on a modern 150-ft. through span it is about 11·5 per cent. Consideration of the resistance to twisting offered by the booms of the main girders leads to the expectation that the fixing will be greater than this; but it will not in the latter case exceed 15 per cent.

The percentage of fixing of the cross girders depends on the type of span considered, and in relatively shallow deck spans the percentage of fixing may reach 80 per cent. After the percentage of fixing is ascertained, it is necessary to check the strength of the connections as regards the transmission of the bending moment. If they are not strong enough a yielding of the parts will take place until the fixing is reduced to a point at which the riveting will transmit the bending moment, and thereafter this percentage of fixing will only be realised under the maximum loadings of the cross girder.

The bending moments on the verticals due to the ascertained percentage of fixing of the cross girders are often very high. In typical cases calculated they increased the direct stress in the vertical by 26·5 and 40·5 per cent. In many cases these stresses rise to 50, 75 or 100 per cent. of the direct stresses in the verticals as usually given by the stress sheet for direct loads.

The proportion of the longitudinal loads carried by the deck system is then considered in detail, and is shown to depend largely on the resistance of the cross girders to lateral deformation. It is also shown that in a single-track 150-ft. span open-decked through bridge, if the cross girders are similar throughout and of average design, the proportion of longitudinal load carried by the deck system is 11·5 per cent., and the bottom boom stresses are relieved to that extent. The end cross girder comes under a fibre stress, due to lateral bending, of 5·48 tons per square inch, and the average longitudinal stress carried by the rail-bearers is 0·414 tons per square inch tension. If now the end cross girder alone is "doubled," the proportion of longitudinal load carried by the deck system rises to about 30 per cent., with a reduction of fibre stress in the end cross girder, due to lateral bending, to 5·35 tons per square inch, and an increase in longitudinal tension on the rail-bearers to 1·06 ton per square inch. A deck plate riveted to the top flanges of the rail-bearers and cross girders and to the booms of the main girders enormously stiffens the upper portions of the deck, so that in the last case considered the fitting of a ⅝-in. flat deck plate caused the deck system to carry 47 per cent. of the longitudinal loads.

The effect of a deck plate in altering the distribution of stress, and the difficulties introduced thereby into the solving of the problem, are considered in detail. Comparative figures for a 150-ft. through-span

double-track bridge are discussed, and the very uneven distribution of longitudinal stress to the inner and outer lines of rail-bearers in double-track spans is pointed out. The possibility of reversals in longitudinal stress along the central longitudinal axis of the deck system in double-track bridges is indicated.

Observed deformations on a 150-ft. deck span are then considered, and from the measured lateral deflections of the end cross girder of such a bridge it is shown that the "give" in the connections may be arrived at by calculation. If there were no "give" in the deck connections of this span the proportion of longitudinal load carried by the deck system would be 26·5 per cent., which is reduced, owing to the actual "give," to 24·5 per cent.

The modifications in the stresses in the cross girders, rail-bearers and deck plating, due to the longitudinal loads carried by the deck system, and also the relief in the boom of the main girder, are indicated. It is thus possible to arrive at a due appreciation of how these may be expected to vary in similar structures, which may be of value in making other designs.

The Ministry of Transport's recent impact tests are considered, and it is pointed out that the outstanding feature of these is the great difference between the stresses in the structures as expected from calculation and those actually found by the Fereday-Palmer stress recorder. It is suggested that part of these variations is to be looked for in the flange action of the deck systems —examples being given from the observed results showing a relief in stress, due to the deck system, ranging from 7½ per cent. to 53 per cent.

The bearing of these studies on modern views of design is discussed, and certain directions are indicated wherein the design of bridge structures might be improved.

POWDERED COAL: ITS PREPARATION AND UTILISATION.*

By R. JACKSON.

THE avenue of promise to the economical utilisation of coal, whether high or low grade, or manufactured smokeless fuel, is that of burning such coals in powdered form, mixed with the correct amount of air for complete and perfect combustion. A system possessing all the flexibility of oil or gas, but being also exceedingly economical and efficient, perhaps it is not remarkable that the progress of pulverised fuel has been much more rapid in other countries than in our own. In France the use of pulverised coal has made great progress, due in some measure to the large percentage of "fines" produced and the limited coal supplies available. The progress made in the United States is phenomenal, and it has been estimated that the annual consumption of pulverised coal exceeds 30 million tons, of which some 2½ million tons is used for steam raising, and it is anticipated that the latter will rise to 3½ million tons in a few months time. The class of coal used is invariably of good quality "run of mine," whereas in France low volatile and waste fuels are commonly used. American coals are usually softer than English coals, and this characteristic has undoubtedly assisted development.

The South American countries, particularly Brazil, have made great progress in the use of pulverised coal. The friable nature and low value of Brazilian coal, practically preclude its economical use in the raw state. It is now being used in powdered form, not only for stationary furnaces, but also for locomotives, and interesting data is given in the Journal of the Institution of Locomotive Engineers, Vol. XII, 1922.

In this country we have been fortunate in having abundant supplies of good hard coals, but the enormous coal consumption is rapidly depleting the better seams, and has led to the working of other coalfields whose product is not so uniformly good and where the proportion of waste is much higher. For example, consider the East Kent coalfields, an area yielding a coal of superb quality, a typical analysis of which is:—

	Lump.	Mixed Slack.	Fines.
Fixed carbon	77·7	77·75	53·62
Volatile	21·9	14·75	23·31
Sulphur	—	0·81	—
Ash	1·3	6·65	23·07
C.V. (B.T.U. per lb.) ...	14,780	12,550	11,715

This is an excellent coking coal, and was greatly in demand in pre-war days by continental buyers. The coal is, however, very friable, and the author is informed that out of the weekly output of 8,000 tons at least 70 per cent. or 5,600 tons are fines. The increasing discrimination of buyers has made the disposal of this fine coal a most difficult matter, and whatever may be the ultimate solution to the problem, an immediate remedy is available in its use as powdered coal.

The history of powdered fuel is most interesting, since it illustrates the slow growth of a new process, and the rapid progress, once such process has been established. The earliest known developments were made in 1818 by an engineer named Niepce, who experimented with the burning of coarse or granular coal (probably fines) in suspension when blown on to a grate fire.

It is somewhat singular that in 1918, one hundred years later, Mr. Hunt, of the United States Shipping Board, should apply the same process and equip a Scotch boiler on board a freight steamer to burn granular fuel of a size from ¼ in. to dust, by blowing it on to a grate fire. The fine particles burned while in suspension, and the coarse particles fell on to the fire bed. The nozzle was flattened to give good lateral distribution, and the air was supplied at 3 lb. to 4 lb. pressure. A similar method is reported to be in successful use at the U.S. Naval Experimental Station at Annapolis, where Mr. Hunt made his initial experiments.

In 1831 a patent was granted to John Samuel Davies of West Bromwich, covering the firing of iron furnaces by coal dust, and between 1840 and 1860 several patents were taken out for this purpose. In 1866 and 1870 Whelpley and Storer took out patents for augmenting ordinary grate fires by coal dust, and proposed the introduction of the dust and air at various specified points. It was not intended to dispense with the ordinary fire, but only to assist and economise. Mr. T. R. Crampton took out patents in 1869 and 1871 and gave a lecture before the Iron and Steel Institute in 1873 in which he gives the results of his observations and experiments.

Interest was now aroused, and numerous patents were registered and plants designed to produce powdered coal and burn it successfully. Much work was done in Germany concerning the firing of cylindrical boilers of the Lancashire and Cornish types, and we are indebted to the late Mr. Bryan Donkin, who investigated the Wegener system, the results of his tests being published in *The Engineer*, Vol. LXXXI, 1896. The tests related to a Cornish boiler first fired by hand on a grate fire and afterwards by powdered coal, the grate having been removed and the flues lined with firebrick. The tests showed an efficiency with grate fire of 54 per cent. and with powdered coal 77 per cent., an improvement of 42·6 per cent. The CO_2 content in the flue gas was improved from 8·7 per cent. to 15·3 per cent. A later German development was the *Schwartzkopff system*, and a syndicate was established in this country to work this system. Mr. Stromeyer, of the Manchester Steam Users' Association, investigated this plant when applied to firing a Stirling boiler at Haydock, Lancashire. The CO_2 content in the flue gases was 14·47 per cent., which must have indicated considerable economy over the usual practice then obtaining.

The time, however, was not yet ripe for boiler firing

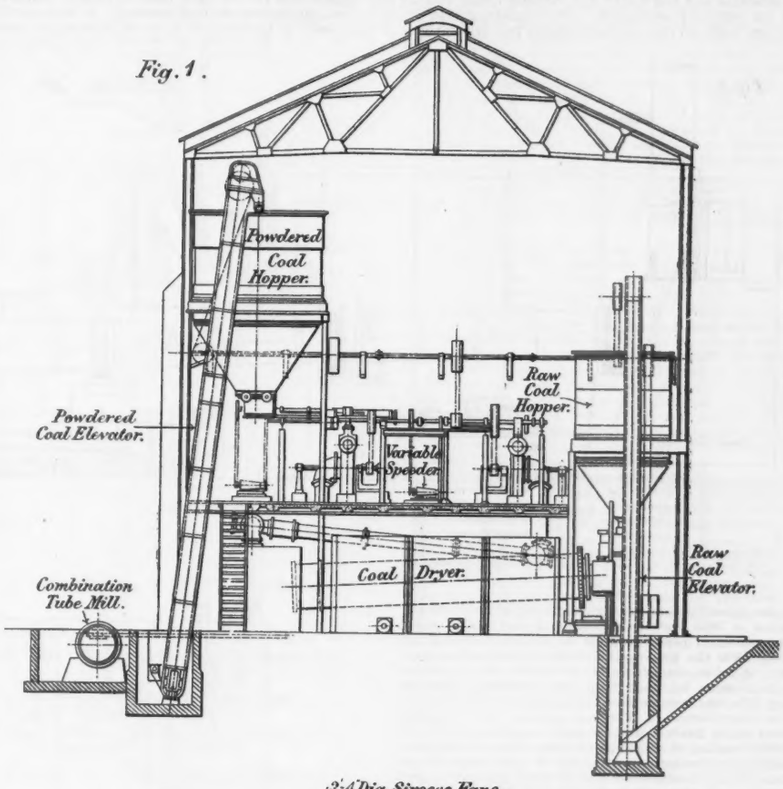


Fig. 1.

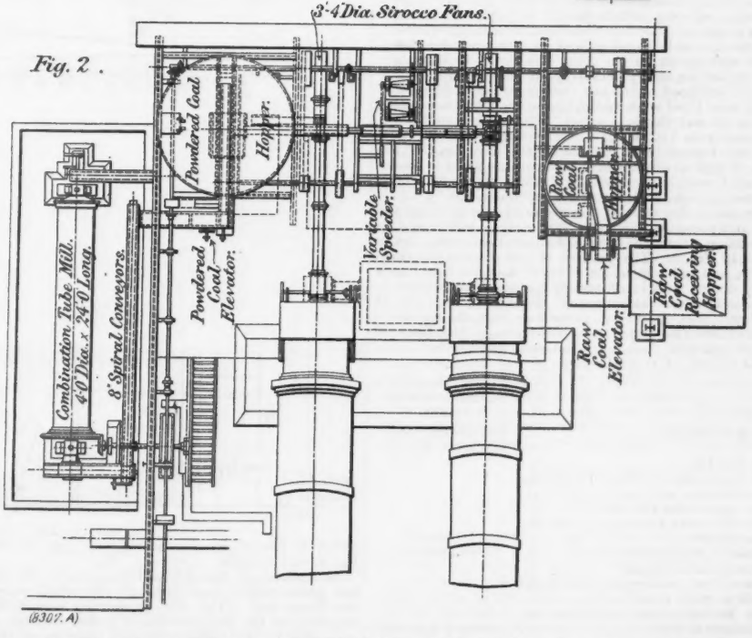


Fig. 2.

* Abstract of paper read before the Midland Branch of the Institution of Mechanical Engineers at Coventry on February 7.

and we are indebted to the cement industry for the eventual success of the process. The rotary cement kiln was invented by Siemens in 1869, and in 1885 Ransome patented a rotary kiln using gas as a fuel. Unfortunately, this kiln did not find immediate favour in this country, where intermittent shaft kilns were in vogue, as the cost of gas or oil was prohibitive.

In the U.S.A. the conditions were favourable to rotary kiln operation, as large supplies of oil and natural gas were available and the rotary kiln became firmly established for cement manufacture. The increasing cost of oil and gas rendered the use of alternative fuel imperative, and the Atlas Company, after much initial work, finally adopted in 1895 the use of powdered coal in lieu of oil. This occasioned rapid progress in powdered coal firing, and by 1900 the use of oil had been practically superseded. English manufacturers were not slow to follow the lead given by their American confrères, and the rotary kiln soon became firmly established in this country.

The manufacture of Portland cement is in England carried on by the wet process, and the cement is a compound consisting of a mixture of lime, silica, and alumina, produced by the intimate mixing of some form of carbonate of lime (limestone, chalk or marl) with the correct proportion of clay, which should be high in silica and low in alumina. The raw materials, after being quarried, are graded, crushed and ground to a fine powder, when mixed with about 30 per cent. of water. In this state it is known as slurry and is pumped from the slurry tanks to the head of the kiln, which might be likened to a steel tube lined with firebrick, and inclined at an angle of 1 in 25 and slowly rotated. The size of such kilns may vary from 6 ft. to 12 ft. diameter and 60 ft. to 275 ft. long, the burner being located at the lower end of the kiln. A typical arrangement of a cement plant is shown in Figs. 1 and 2, page 381, while Fig. 3, on this page, illustrates a kiln, with slurry tanks, cooler, &c.

The slurry descends at the required rate through the kiln, and passes through the evaporating, calcining and combustion zones, a typical temperature curve being shown in Fig. 4. The product of this process is termed clinker, and falls out of the lower end of the kiln into a rotary cooler, and is ultimately ground into cement.

Since the cement industry developed the use of powdered coal, it is not surprising that the methods adopted for preparing the coal followed the lines of cement practice, and a typical coal preparation plant would consist of the following:—

	Power taken for a 2-ton per hour plant.
Raw coal elevator	Conveyors and elevators, 6–8 h.p.
Raw coal bin...	—
Coal dryer with feeding and driving mechanism, and fan to withdraw the gases from the dryer	8 h.p.
Tube mill, with feeding and driving mechanism...	100 h.p.
Powdered coal elevator	See above.
Powdered coal hopper	"
Feeders for conveying powdered coal to blast fans	"
Fans for delivering coal and air mixture to kilns	2 fans, 8 h.p. each.

Such a plant is operated on the storage system, as it involves the storage of the powdered coal, and is distinct from the unit system which prepares and utilises the product as produced. Both systems will be described in detail.

Storage Systems.—The use of various elevators, conveyors, &c., will be clearly understood, and it is intended to confine the description to the various types of coal dryers, feeders, pulverisers, and burners commonly used.

Dryers.—The function of the coal dryer is to rid the coal of its extraneous moisture prior to pulverising, as the output of the usual type of pulveriser is greatly reduced by any surface moisture in the coal, and 5 per cent. of moisture would probably decrease the pulverising capacity by 20 per cent. There are also great difficulties connected with the storage, feeding and burning of coals containing moisture, all of which will be appropriately dealt with.

There are many types of dryers in use, but in general they consist of a tubular shell inclined axially supported on rollers and driven through gearing. A large portion of this shell is enclosed in a brick housing or oven, which is heated by a separate grate fire, as shown in Fig. 5, on this page.

In addition to the external heat due to the fire, the hot gases usually pass through the shell, entering at the lower end. The raw or undried coal is fed into the shell at the higher end and passes through the hot zone due to the inclination and rotation of the shell. A series of longitudinal baffles extend throughout the shell interior, which have the effect of lifting and turning the coal during its progress, thus exposing a maximum surface to the drying influence of the hot gases. The liberated moisture and hot gases are exhausted from the dryer by a fan and delivered to the stack. There are several important points to be observed in efficient dryer operation. (1) The moisture content must be reduced to 1 per cent. or thereabouts. (2) The coal should leave the dryer as cool as possible. (3) The temperature inside the dryer should be limited to 220 deg. F. in order to prevent loss of light volatile matter. (4) The speed of the hot gases through the dryer should be low, so as to entrain a minimum amount of coal dust.

It will be perceived that good results are contingent upon careful operation, and the dryer is usually a most inefficient item of plant. The amount of coal used to heat the dryer may vary from 1 per cent. to 5 per cent. of the coal dried according to the moisture content of the latter, and the condition of the plant. Vertical dryers are now being designed to utilise a percentage of the hot flue gases which are drawn through the dryer by a fan. The coal descends through a louvered pipe, and the hot gases and air have free access to the coal, the amount of power required to operate the fan being about 3½ kw. per ton of coal dried. This may be fairly satisfactory for granular coals, but would hardly be suitable for ridding fines or smudge of high moisture contents.

Pulverisers.—The most common type of pulveriser in use in this country is the tube mill, sometimes operated in conjunction with a ball mill, the latter acting as a preliminary and the former as a final pulveriser. The coal under such circumstances would enter the ball mill in the centre, falling amongst the balls while the mill is rotating. The effect of concussion as the balls fall and roll from plate to plate, and the attrition between the balls and plates quickly breaks down the coal until it is sufficiently fine to pass through the perforated plates and sieves. The residues fall back

Fig. 3.

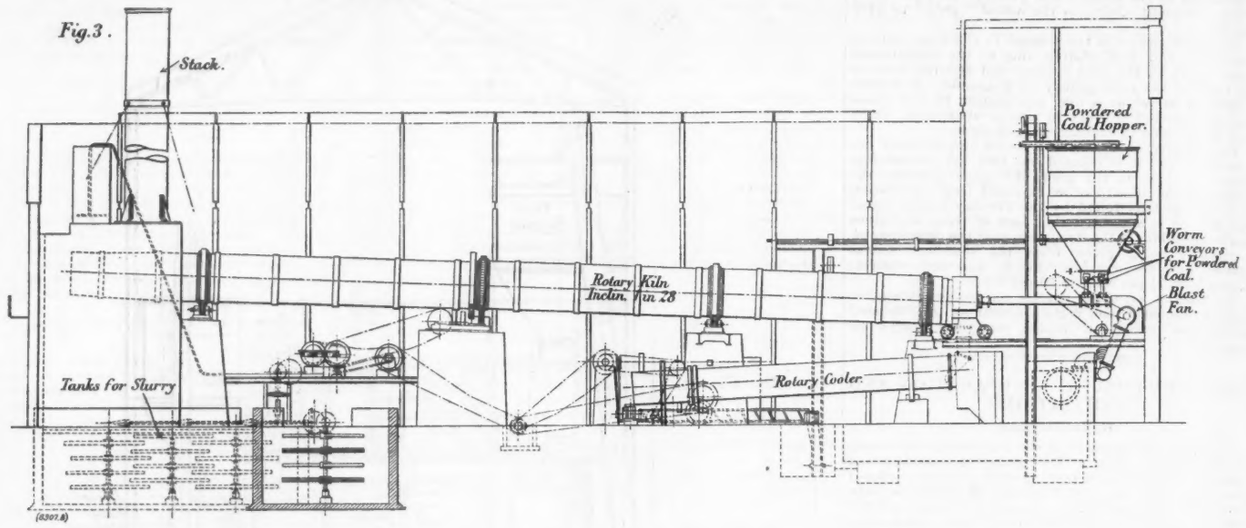


Fig. 4.

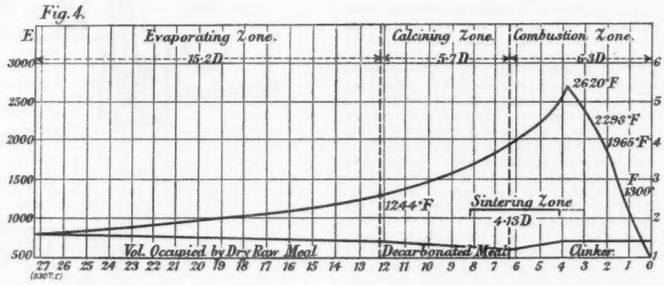
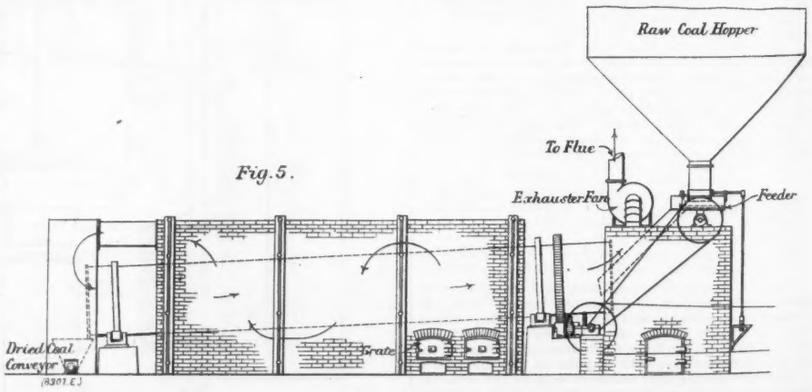
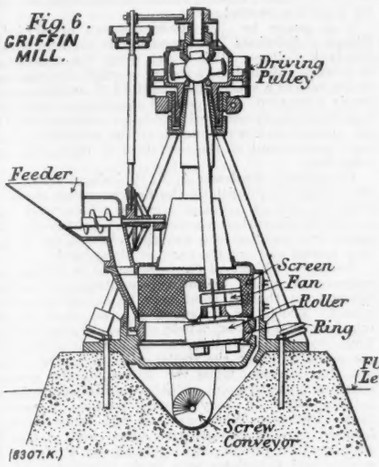


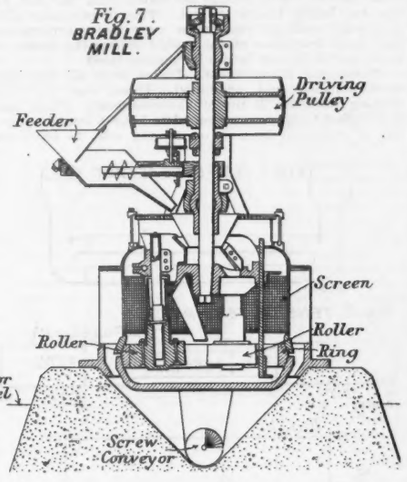
Fig. 5.

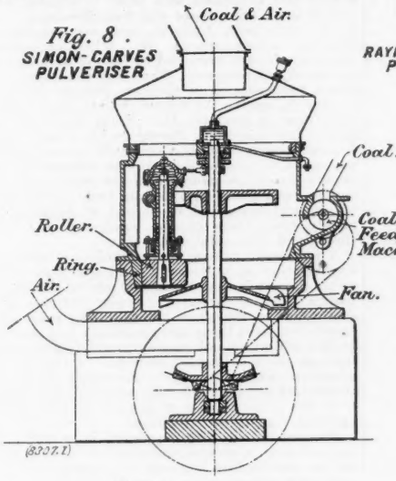


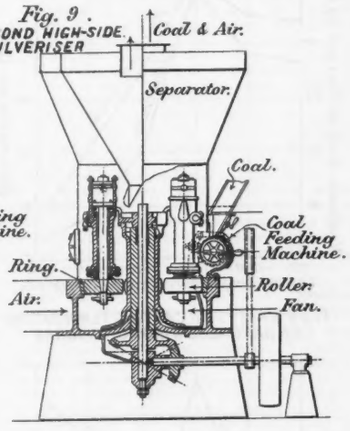
into the mill until further reduction takes place, and the fine particles pass along to the tube mill for final grinding.

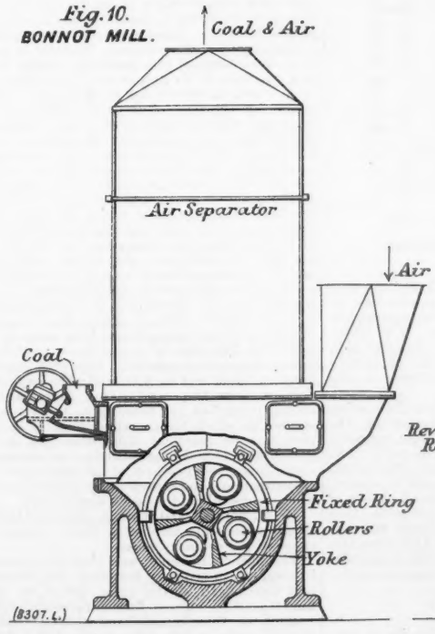
The tube mill usually consists of a riveted steel cylinder supported on hollow trunnions, and rotated at constant speed by gearing. The interior of the mill is lined with cast-iron plates, and the grinding medium consists of chilled cast-iron balls, pebbles or other materials. The coal is fed through one trunnion, and the finished product delivered through the other. A mill of 2 tons capacity per hour would probably be 5 ft. diameter by 22 ft. long, and would contain 6 tons of balls or pebbles when running at 28 r.p.m. It will be observed that the output of such pulverisers in relation to the total weight, power required and space occupied appears disproportionate, yet notwithstanding the tube mill enjoys a measure of popularity, probably because of its general immunity from breakdowns. It is, however, an inefficient apparatus, and much experimental work has been done to improve its performance.

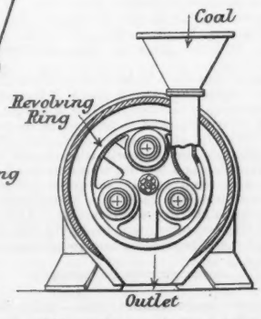












The author is indebted to Mr. Chas. Blyth for photographs taken during his investigations into this question, and are actually taken from an experimental tube mill in operation, the end being covered with glass so that the peculiar action of the grinding medium could be clearly understood. These experiments indicated that there was a definite relationship between the surface of the grinding body and the surface produced on the ground material, large balls being suitable for the production of coarse material and small balls for fine material. Also that the tube mill was most efficient when the quantity of balls occupied about 44 per cent. of the cubical capacity of the mill. This led to the evolution of the cylpeb, a cylindrical piece of hardened steel, whose length must be expressed in terms of diameter for efficient results, and later to the development of holpebs, which differed from the cylpebs only in respect that they were hollow.

The movement of cylpebs and holpebs in a mill is most interesting, as they do not roll but move endwise with the rotation of the mill, and always follow the same direction.

Space and time limitations will not permit further lingering over this absorbing topic, but it must be stated that the evolution of holpebs has done much to improve grinding practice in tube mills.

Pendulum Mills.—The Griffin mill, Fig. 6 on this page, was introduced about 30 years ago, and consists briefly of a roll head which carries a long pendulum arm on the lower end of which is mounted a roll, which makes contact with a steel die ring. When the roll head is rotated the pendulum arm also rotates, but the end carrying the roll is free to move outwards. The coal is crushed by the pressure exerted between the roll and the die, due to centrifugal force, and it is stated that the 30-in. Griffin mill exerts a pressure of 6,000 lb. and the 40-in. Grant 15,000 lb.

The Bradley mill, Fig. 7, differs from the Griffin mainly in that it has three rolls, the pendulums being supported from a yoke mounted on a central shaft, the fine material passing through screens at the outside of the die.

The Simon Carves and Raymond pulverisers, Figs. 8 and 9, on this page, are of suspended pendulum type, the former having three rolls and the latter four or five rolls. They differ from the previous mills of this type by being totally enclosed, the ground product being drawn away by a fan. It is usual to make the upper part of the casing into a grading or elutriation chamber, where the air velocities fall so low as to allow the coarse particles to precipitate into the grinding zone, and the fine particles remaining in suspension are then delivered to the storage hoppers.

The principle of the Roulette and Fuller mill is similar, though details of construction are different, and pulverising is done by the pressures exerted by balls running in a race. The balls are rotated by a pusher mounted on a vertical shaft, the coal being fed by suitable means between the balls and is quickly reduced to granular and pulverised state. The fine material is entrained on air currents passing through the mill, and may be graded by passing through screens or elutriation chambers. The coarser particles fall back into the mill for further reduction.

The Sturtevant and Bonnot mills differ in principle. In the former type the ring or die is rotated, and pulverising is performed by the elastic pressure of rolls. This pressure can be varied to suit the class of pulverising under consideration. The Bonnot mill has a stationery ring, the rollers being rotated by a spider and pulverising is done by the effect of centrifugal force. This latter mill is fitted with a chamber for air separation. Both are horizontal mills, and do not necessitate the use of vertical shaft motor, bevel gears or twisted belts. The Bonnot Mill is illustrated in Fig. 10 and the Sturtevant Mill in Fig. 11.

It will be noticed that all these mills pulverise by the pressure exerted between two surfaces, and it will be apparent that as the weight of the roll or ball decreases due to wear, the pressures exerted will also decrease and consequently the output of the mill be reduced. (This is not intended to apply to Sturtevant mills where the pressure is applied mechanically). Therefore the output of the mill must bear some relationship to the pressures exerted, and thus to the power absorbed or energy account, and this point will be discussed later.

(To be continued.)

STREET TRAFFIC IN THE UNITED STATES.—According to *Engineering News Record*, New York, people are slowly beginning to realise that the traffic problem in American cities is too big for policemen, chambers of commerce, or merchants' associations. The engineer is being recognised as the only proper agent of reform. As yet, the recognition is halting, and in but few instances has it gone as far as the actual commission to set to work; but the leaven is working, and the rest will come in time. Our contemporary quotes the *New York Tribune* as stating that the providing of New York City with permanent and adequate avenues of traffic is a greater engineering undertaking than the Panama Canal or the Catskill Aqueduct. Only a commission formed of experienced engineers and progressive business men can deal with the problem in the present or in the future. Both from the point of view of engineering and of finance the task on hand is of unprecedented magnitude. It must be approached scientifically.

THE EFFECT OF CASTING TEMPERATURE ON THE PHYSICAL PROPERTIES OF A SAND-CAST ZINC-BRONZE.*

By FRANCIS W. ROWE, B.Sc., Member (Manchester).

THE object of this investigation was to determine, for works use, the optimum casting temperature to give the required mechanical properties in a gun-metal of the composition specified. The author realises that the results would have been more valuable had they been extended to cover the effect of variations in mass and other methods of casting and moulding.

The alloy used is one which gives very satisfactory service for castings which must have good strength and toughness, and is one which is very easy to handle in the foundry. The nominal composition is: copper, 88 per cent.; tin, 6 per cent.; zinc, 6 per cent.

In practice a lead content with a maximum of 1 per cent. is permitted, and a maximum variation of tin and zinc contents of 0·75 per cent. either way. The alloy is usually made up in the following manner: virgin mixture (88 : 6 : 6), 33⅓ per cent.; remelted borings of same alloy (with corrections), 33⅓ per cent.; heads and runners of same alloy, 33⅓ per cent.

The ingot copper, ingoted borings, heads and runners are melted under charcoal, and the tin and zinc added after the pot is withdrawn from the fire at a temperature of 1,250 deg. C. to 1,275 deg. C.

The author has several times made freezing-point determinations of different samples of this alloy and found that the primary solidification begins at 1,005 deg. C. ± 7 deg. C.

Method of Making the Test-Bars.—Six boxes of test-bars were moulded. Each box contained two 14 in. by ¾ in. diam. bars moulded horizontally in green-sand. Each box (*i.e.*, two bars) was run with a down runner 1¼ diam., terminating in a splay to both bars. The splay fed both bars at the end at practically the full diameter. The riser was exactly similar to the runner. Fig. 1 shows a sketch of the finished test-bars. One hundred and twenty pounds of the alloy (made in the usual manner from scrap and virgin metal) were melted in a forced-draught pit furnace in a 150-lb. Morgan Salamander crucible. The metal was in the fire 63 minutes. After drawing the pot the necessary tin and zinc were added and the boxes cast. The temperature of the metal prior to pouring each box was taken with a Foster base-metal bare thermocouple, previously calibrated against a standard platinum—platinum-rhodium couple and found accurate to ± 2 deg. C. over the range used.

The boxes were cast at the following temperatures: No. 1, 1,210 deg. C.; No. 2, 1,170 deg. C.; No. 3 1,130 deg. C.; No. 4, 1,090 deg. C.; No. 5, 1,050 deg. C. No. 6, 1,020 deg. C. In the case of the last box to be poured, the metal was too stiff to fill more than half the riser—*i.e.*, the solidification of the castings had taken place before sufficient metal had flowed through to fill the riser.

It was noticed that the runner heads on those boxes cast at the highest and lowest temperatures were quite flat, but those cast at intermediate temperatures were slightly sunken.

Analyses of Test-Bars.—Two analyses were made, one on drillings from the bottom of the runner of No. 1 bars, and the other on drillings from the riser from No. 5 bars. As these two analyses only differed within the limits of analytical errors the average is given below: copper, 87·96 per cent.; tin, 6·08 per cent.; lead, 0·52 per cent.; zinc, 5·31 per cent.; iron, 0·02 per cent.; phosphorus, 0·021 per cent.

No estimations of arsenic and antimony were made, as the foundry uses only "Lamb and Flag" tin and the highest grades of "best selected" copper, and previous determinations have shown these elements to be present in negligible quantities.

Physical Properties of the Bars.—Each bar was divided into three pieces—an 8½-in. length from the end for tensile tests, a 5½-in. length from the other end for Izod impact and hardness tests, and a ½-in. piece from the centre for microscopic examination. The tensile test piece was machined as shown in Fig. 2. The Izod test piece was the B.E.S.A. standard 10 mm. sq. bar with three notches. The yield-point was taken with a pair of dividers in the usual workshop manner, and so no great value can be attached to those figures. Hardness tests were made with a Brinell machine using a 10-mm. ball and 500-kg. load on the Izod pieces after breaking. The Izod figures were obtained on the 120-ft./lb. Avery-Izod machine. The results are tabulated below.

Test Results.

No.	Casting Temperature. Deg. C.	Yield-Point. Tons per Sq. In.	Maximum Load. Tons per Sq. In.	Elongation on 2 In. Per Cent.	Izod Impact. Ft.-lb. Average.	Brinell Hardness Number
1	1,210	7·9	17·3	37	13·8	51·8
1A	1,210	7·8	16·9	35	13·6	50·3
2	1,170	8·0	17·4	39	21·8	54·3
2A	1,170	8·1	17·3	38	20·7	56·0
3	1,130	8·2	18·4	50	23·3	57·7
3A	1,130	8·2	18·7	51	28·0	58·6
4	1,090	8·1	14·5	18	18·0	60·5
4A	1,090	8·2	15·6	23	18·0	59·6
5	1,050	8·0	11·0	6	16·2	61·5
5A	1,050	8·1	13·4	10	15·8	60·5
6	1,020	8·2	10·2	4	17·0	62·5
6A	1,020	—	Badly blown	—	16·0	63·6

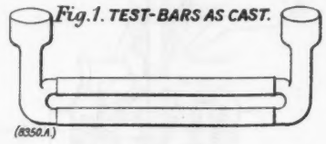
* Abstract of a paper read at the meeting of the Institute of Metals on Thursday, March 13.

The averages of the two results for each bar are shown graphically in Figs. 3 and 4. The fractures of the bars Nos. 1 to 3 showed a close crystalline structure. Nos. 4 to 6 showed a rather coarse granular structure with white specks. The tensile test-piece from bar No. 6A was too badly blown to test. This is common with greensand castings cast at a very low temperature. Any local dampness of the mould causes the metal to blow, and it has set before it recovers itself.

Microscopic Examination.—Pieces from all the bars were polished and examined. There was no very striking difference in any of the specimens. Those cast at a higher temperature seemed to have a smaller quantity of eutectoid present, or, at any rate, to have the eutectoid more finely dispersed. The dendrites were also straighter and longer than in the samples cast at the lower temperatures. The macroscopic appearance of the pieces showed a marked difference. The grain-size grew much smaller as the casting temperature fell. It was quite easy to place them in order of casting temperature without knowing the numbers of the samples.

Discussion of Results.—It is obvious that the casting temperature exerts a very marked influence on the physical properties of the alloy. The optimum temperature is very clearly marked in this series of tests. The yield-point shows no appreciable variation. The Brinell hardness figure rises continuously with the fall in casting temperature, which is a feature common to all classes of gun-metals and bronzes. It is quite probable that different sizes of test-bars might give appreciably different results, as also might dry sand-moulds. Therefore this optimum casting temperature is probably only applicable to castings of a similar section and moulded in a similar manner.

Fig. 1. TEST-BARS AS CAST.

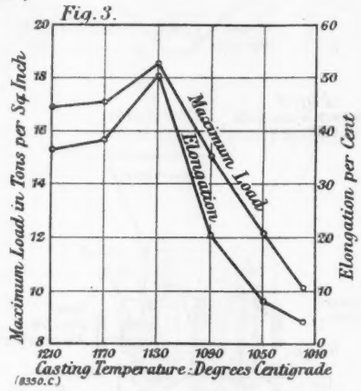


(8350.A.)

Fig. 2. TENSILE TEST-PIECE.

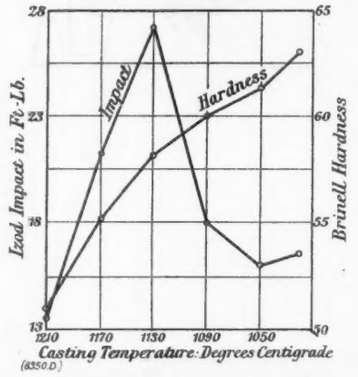
(8350.B.)

Fig. 3.



(8350.C.)

Fig. 4. EFFECT OF CASTING TEMPERATURE ON HARDNESS & IMPACT FIGURES.



(8350.D.)

PHOTOGRAPHY FROM AEROPLANES.—A handbook containing a detailed description, with numerous illustrations, of the L.B. type aero-camera has recently been issued by the Air Ministry and is obtainable from any of the branches of H.M. Stationery Office [price 3*s.* 6*d.* net].

THE PHYSICAL SOCIETY OF LONDON.

AT the meeting of the Physical Society of London held on February 22, at the Imperial College of Science, Mr. F. E. Smith, C.B.E., F.R.S., in the chair, the following papers were read:—

1. A paper on "*A Generalisation of Whitehead's Theory of Relativity*" was read by Mr. G. Temple, B.Sc., Birkbeck College. This paper gives the generalisation of Professor Whitehead's theory of relativity appropriate to the case of a space-time manifold of uniform and isotropic curvature. The general equations of the gravitational and electromagnetic fields are obtained, and these are applied to the discussion of the problems of planetary motion and of the deviation of light rays in the solar field.

Discussion.—Professor A. N. Whitehead congratulated the society on publishing the first paper on this subject from the pen of a young scientist whose work augurs a very distinguished career. The mathematics in the paper were handled in a way that showed the author to be a master and not the slave of his symbols.

Professor Whitehead then proceeded to indicate some respects in which his own presentation of relativity differs from that of what may be called the orthodox school. The latter recognises only one field of natural relations, that is to say a field which is wholly contingent. Thus, to specify an interval on Einstein's theory it is necessary to know the distribution of matter throughout the universe, since the nature of the space-time continuum at any point-event is conditioned by the gravitational effect of every existing particle, however distant. Professor Whitehead, on the other hand, puts forward a more conservative view—and in this he is supported on philosophical grounds by Professor Alexander—and postulates two fields of natural relations, one of these (viz., space and time relations) being isotropic, universally uniform, and not conditioned by physical circumstances; the other comprising the physical relations expressed by laws of nature, which are admittedly contingent. Thus by considering the intrinsic properties of an adequate part of the universe it is possible, on the Whitehead theory, to determine that space-time is isotropic throughout that part, and to infer that it is isotropic throughout the whole; but in the Einstein theory there is a serious difficulty in definining any units of measurement in the absence of complete knowledge of the structure of the whole universe, and consequently there is no definite basis for the expression of physical laws, and no means of determining completely the nature of the continuum (*i.e.*, the $\mu\nu$) throughout even a finite part of it.

A further advantage of distinguishing between space-time relations as universally valid and physical relations as contingent is that a wider choice of possible laws of nature (*e.g.*, of gravity) thereby becomes available, and while the one actual law of gravity must ultimately be selected from these by experiment, it is advantageous to choose that outlook on nature which gives the greater freedom to experimental inquiry. Of the various laws consistent with this oulook Einstein's is one, but its theoretical aspect is different according as it is regarded from the point of view of one or the other of the two postulates under consideration.

The aim of the Einstein theory is to derive physical laws of such a general character as to be independent of the peculiarities imposed on measurements by the particular circumstances in which they are made. But this is an arbitrary demand; it may well be that those peculiarities are expressions of the essential realities underlying the phenomena. To take a parallel case: If we are interested in a particular ellipse, we may arrive best at some of its properties by thinking of it simply as a curve, at others by thinking of it as a conic, at others by thinking of it as an ellipse; but we shall arrive at other properties of great practical value by considering its particular dimensions and position. Einstein's view is analogous to regarding the first-mentioned properties as objectively real while regarding the last-mentioned properties as accidents arising out of the point of view of the observer. In investigating the laws of nature what really concerns us is our own experiences and the uniformities which they exhibit, and the extreme generalisations of the Einstein method are only of value in so far as they suggest lines along which these experiences may be investigated. There is a danger in taking such generalisations as our essential realities, and in particular the metaphorical "warp" in space-time is liable to cramp the imagination of the physicist, by turning physics into geometry. The case is a little like that of a metaphor used by Dr. Routh in lecturing on metacentres. He would draw a ship on his hand in chalk and rock it, and then explain that "you now remove the sea." This illuminating figure of speech if applied too literally to the particular circumstances to which the naval constructor is limited would give rise to practical difficulties. In short, it seems undesirable to make (as Einstein does) extreme generality—the being independent of all particular conditions of measurement—the criterion by which the real character of the physical field is to be determined.

Mr. T. Smith asked whether the curvature of 4-dimensional space-time implied a limit to the extension of space in the ordinary sense.

The author, in reply, said that in the same way that in a sphere, in ordinary geometry, the area of the surface and the length of the great circles, or geodesics, are limited, so in curved four-dimensional space-time the volume of three-dimensional sections and the length of the geodesics (viz., the paths of the event-particles) are limited. In curved space-time the experiences of a particle of matter must repeat themselves periodically.

2. A paper on "*The Structure of the Atomic Nucleus and the Mechanism of its Disintegration,*" by Dr. Hans

Pettersson, Göteborgs, Högskola, Sweden, was read by Dr. J. H. Vincent in the absence of the author. Of this paper the following is an abstract: In interpreting the results of their experiments on the disintegration of certain light atoms by the impact of α-particles, Rutherford and Chadwick have supposed that the α-particle transfers its momentum by direct impact to a proton which is a satellite to the rest of the nucleus. The paper gives arguments for an alternative hypothesis which assumes that the α-particle exercises a trigger-action, precipitating an explosion of the nucleus which is supposed to have only a limited stability in the case of each of the elements.

Discussion.—Professor C. N. da C. Andrade said he had listened with interest to Dr. Pettersson's paper, but thought it would have been of greater value if some of the experiments foreshadowed at the end had been performed before the theory was propounded. We know so little of the structure of the nucleus of even the lightest elements that the time seems hardly ripe for a decision between the two theories put forward, especially as the distinction between the satellite and explosion theories is mainly a question of words at the present stage. We know, from the energy of the released proton, that the α-particle must exercise some kind of trigger-action in the cases under discussion, but whether the released proton comes from inside or outside the nucleus is mere speculation. The only experimental evidence put forward is that given in one of the tables where the agreement between the second and third columns is not striking. The satellite hypothesis is merely tentative in the absence of sufficient experimental knowledge, but in any case it does not necessarily imply a direct hit between an α-particle of normal size, and a proton, for deformation of the α-particle takes place in such circumstances so that the value of n/Q does not necessarily involve the validity of the theory as is suggested. The claim that the explosion hypothesis makes it possible to preserve Coulomb's law counts for little, since Coulomb's law cannot account for the stability of a nucleus composed of positive and negative charges, which when free would be about as large as the nucleus itself. The position is much as if a man having measured up a box and guessed from shaking it that it contained pieces of metal were to start speculating on the dates of the coins inside it. The appeal of the explosion hypothesis is to what may possibly be found in future experiments rather than to anything now known.

The new piece of information which has been brought forward is that, it is claimed, the nuclei of Be, Mg and Si undergo disintegration on bombardment. If this is confirmed it is, of course, important, but it furnishes a poor basis for such a load of speculation.

Dr. J. H. Vincent said the letter of Bates and Rogers to which Pettersson gives the reference was written in consequence of one from Kirsch and Pettersson of September 15 in the same journal. They consider it possible that the particles observed by Kirsch and Pettersson may be α-particles from the active deposit. It seems that the view of Bates and Rogers on the particles of 18 cm. range which they found, and which Pettersson mentions in the footnote, was that they were probably due to "natural" H-atoms, and not to the products of disintegration.

If it should turn out that the view advocated in the paper is true, and that all atoms are liable to disintegration, it would provide a simple explanation of a very puzzling circumstance in connection with the possibility of deriving all the elements from some parent source. If an H-particle could be removed by bombardment from a member of a radio-active series, the residual nucleus might still be radio-active, and would then take its place in another radio-active family, such that its members would have atomic weights distinguished from those of the family to which it originally belonged by the remainder, on dividing by 4, being one less than for the original series. Thus an isolated radio-active atom would give rise to a pure progeny, while a collection of radio-active atoms originally all belonging to one family would become contaminated by the other three families possible on this hypothesis.

The author refers to the problem of "packing." The theoretical source of available energy provided by condensing hydrogen into helium arises from the view that mass and energy are equivalent, 1 gram being c^2 ergs. It seems that it might be possible to test the matter experimentally. Hydrogen under pressure and in an enclosure at a high temperature should, if even a small fraction changes into helium, take up a temperature higher than the walls of the enclosure.

The problems of disintegretion may possibly be amenable to study by means of calorimetry. Thus a radio-active source might be found to yield a less supply of heat when pure than when mixed with an element capable of disintegration.

The power of yielding long range H-particles on bombardment is one property of an atom which seems to depend to a large extent on whether its atomic or Moseley number is odd or even. Aston gives other examples of this interesting connection. For tabulating such properties it was found very convenient to draw out the periodic table in such a way as to separate the odd and even Moseley numbers. Thus in this scheme for the first 18 elements:

H							He
1							2
Li	B	N	F	Be	C	O	Ne
3	5	7	9	4	6	8	10
Na	Al	P	Cl	Mg	Si	S	A
11	13	15	17	12	14	16	18

Those from which Rutherford has obtained long range H-particles, viz., 5, 7, 9, 11, 13 and 15 are grouped together.

Captain C. W. Hume said if the impact of α-particles has a trigger effect on light atoms, it would seem that a similar effect might be expected when α-particles impinge on heavier nuclei which are known to be unstable or explosive, viz., those of radio-active elements. In this case should not the rate of decay of such elements be increased by bombardment? For instance, radium emanation should have a shorter decay period when compressed than when rarified, since there would be more frequent impacts in the former case. No doubt it would be difficult to detect so small an effect, but if such an experiment could be devised it would throw light on the question raised by the author.

The author's reply will be published in the Proceedings.

3. A paper on "*The Effect of a Magnetic Field on the Surface Tension of a Liquid of High Susceptibility*," by Winifred L. Rolton, B.Sc., and R. Stanley Troop, B.Sc., East London College, was read by Mr. Troop. In this paper a method of measuring surface tension recently described by Dr. A. Ferguson has been applied to test solutions of ferric and manganese chlorides for the effect mentioned in the title. The results are negative.

Discussion.—Dr. D. Owen said that the paper represented a careful piece of work, which seemed beyond question to show that no effect on surface tension as large as 1 in 1,000 was present when $H = 20{,}000$ was used. The subject lent itself admirably to the application of Dr. Ferguson's recently published method of measuring surface tension, in which a volume of liquid no greater than some tenth of a cubic millimetre was necessary. He would like, however, to make a simple calculation which leads to the conclusion from energy considerations that no observable magnetic effect is to be expected. The effect of the field is to produce magnetic energy $(\mu - 1)\ H2/8\pi$ per unit volume of the specimen, over and above that produced in air. Taking $(\mu - 1)$ as approximately 10^{-4} for iron salts, and $H = 20{,}000$, this amounts to 1,600 erg/c.c. Assuming the thickness of the surface-film to be 10^{-8} cm., the result is to add to its potential energy per unit area the quantity $1{\cdot}6 \times 10^{-5}$ erg. As the surface tension is 75 erg/cm.^{2}, the change is only one part in five millions which is quite beyond the power of detection.

Reference is also made in the paper to the effect of electrification on surface tension, and this effect is also relegated to the category of the minute and unobserved. But in this case the existence of a double electrical layer of molecular thickness does permit of a sensible change in the potential energy per unit area of a surface layer, as is manifested in the electro-capillary effect.

Mr. T. Smith illustrated the frequency distribution of the errors and the limits suggested for the probable errors, as obtained from the figures quoted in the earlier paper by Dr. Ferguson and the present paper. In the former case only one observation out of twenty-eight lay definitely inside these limits. He thought the conditions necessary to justify the application of the formula used were not satisfied in these cases. The uncritical use of such a formula, which gives a value of the form $\epsilon\, n^{-\frac{1}{2}}$, where ϵ is proportional to the average departure from the mean and n is the number of observations, leads in an extreme case to the result that a value true within any assigned limits, no matter how close these may be, will be obtained if the observations are sufficiently numerous, provided they are all of the same quality, no matter how bad that quality may be. So absurd a conclusion showed that the use of the formula required justification.

Dr. P. E. Shaw (communicated): These experiments have an important bearing on the theory of the constitution of matter. The intrinsic pressure in a liquid abruptly ceases at the surface, and the unbalanced normal forces there give rise to the superficial effect called surface tension. He suggested that the authors might employ a magnetic field normal to the surface. This could be done, of course, by having vertical lines of force, the pole pieces being bored to receive the capillary tube. Probably the authors have noticed a paper in the *Phil. Magazine* last January on the effect on surface tension due to an electrostatic field.

The authors' reply will be published in the Proceedings.

CARBON TETRACHLORIDE FOR FIRE EXTINCTION.—Recent experiments made in Hamburg, Zürich and elsewhere favour the use of carbon tetrachloride for extinguishing fires of benzine, petroleum, calcium carbide, carbon disulphide, and also of electrical apparatus. A jet of this chemical is a non-conductor, and leaves no solid or liquid residue which would spoil the material to be protected. The vapours of hydrochloride liberated when the tetrachloride is applied give warning of danger. No accidents due to poisoning were reported by the committees of the two places we mentioned, but such cases have occurred in America, for instance, where the tetrachloride possibly contained dangerous impurities such as trichlorethylene. A burning high-tension generator was quickly extinguished by tetrachloride, whilst the dry powders first applied had no effect. The general objection against dry powders is that they are carried away by revolving machinery, and that they get into crevices and valves which are difficult to clean afterwards. Flames from parts carrying 250,000 volts have been suppressed by these jets. It is interesting that water jets may also be directed on switchboards and electrical machinery, provided the man holding the horse is not too close to the fire. When the water jet from an insulated hose was playing upon an arcing lightning arrester of the horn type, the current did not travel back to the hose until the man approached the arc within less than a foot. No current escape was observed in various experiments at distances of 4 m., which is therefore considered a safe distance.

CATALOGUES.

Gas Producers.—Several types of gas producers with cleaning apparatus, &c., are illustrated in a catalogue received from the Dowson and Mason Gas Plant Company, Limited, Levenshulme, Manchester. The producers are adapted for using for fuel coal, coke and wood, as well as various refuse products of grain and fruit.

Portable Air Compressors.—Complete units for compressing air for operating pneumatic tools are dealt with in a special catalogue issued by Messrs. Reavell and Co., Limited, Ipswich. Five sizes are shown with engines ranging from 8 h.p. to 42 h.p., mounted on trucks for portability. They are specially suitable for use in connection with road breaking, demolishing buildings and other outdoor work.

Steam Engines.—A catalogue specially dealing with horizontal engines for moderate steam pressures (60 lb. per square inch to 100 lb. per square inch) and capable of developing from 2 h.p. to 300 h.p., has come to hand from Messrs. Robey and Co., Limited, Lincoln. The powers stated are developed at economical loads and all sizes will of course carry much greater maximum loads. All the engines are fitted with slide valve gears of which four types are employed. Tables of the standard powers, dimensions, weights and all necessary particulars are given in the catalogue, and the text will form a useful guide in the selection of a suitable engine. Boilers of the locomotive and horizontal multitubular types are also shown in the catalogue.

Pipe Fittings.—A four-page catalogue of Skinner steam-pipe fittings received from Messrs. W. H. Willcox and Co., Limited, 38, Southwark-street, London, S.E.1., is of practical interest, especially to engineers in mills where a large amount of steam piping is employed. The fittings include a clamp which can be fixed against a leaky screwed joint and is provided with means for pressing a packing ring into the thread and against the end of the elbow or socket. A similar construction modified to close leaks at both ends of a socket and a clamp with screwed boss for making a tee branch are also dealt with. These fittings are of malleable iron and can be applied without dismantling the pipe. Particulars are also given of a pipe-bender and of valve re-seating tools. The fittings are listed in standard sizes to suit a wide range of sizes of piping.

Water-Tube Boilers.—The Vickers-Spearing Boiler Company, Limited, 20, Kingsway, London, W.C.2, have sent us a copy of the new edition of their catalogue of water-tube boilers which include those of the header type with straight tubes and of the vertical type with straight or bent tubes. About three out of four water-tube boilers made are of the header type, which the firm state has proved itself the most reliable, adaptable and safest form, particularly for high pressures. Mechanical stokers, superheaters, and the necessary fittings for firing with coal, oil, gas or pulverised coal, are also shown, the last-mentioned fuel giving the largest evaporation per square foot of heating surface. A number of portable water-tube boilers of the header type are made, by the firm and particulars of these are given in the catalogue. Both illustrations and descriptive matter are excellent and the tables of technical information included will be found useful.

Excavators.—The drag-line excavator which has several advantages over the steam shovel for certain applications, is generally of larger capacity than the latter type of machine and is also capable of excavating below its own level and sweeping its bucket over a wider area. Messrs Ruston and Hornsby, Limited, Lincoln, who have long experience in the construction of these machines, have sent us a new catalogue in which their applications are explained and their construction illustrated and described. Operations in digging trenches, canals, reservoirs, &c., taking sand or gravel from pits, cleaning the bottoms and sides of water courses and reservoirs, and facilitating constructional work of all kinds, are illustrated by photographic reproductions. The machines are mounted on road or rail wheels or on caterpillar tracks, and are arranged for steam or electric driving according to requirements. A table of dimensions of five standard sizes with buckets holding from 1 cubic yard to 10 cubic yards, is given in the catalogue together with a chart showing the working radii. We illustrated and described a large example of a drag-line excavator by Messrs. Ruston and Hornsby, Limited, on pages 763 and 795 of our last column.

Oil Engines.—Oil engines ranging from 6 to 150 brake horse-power, and of several types to suit nearly all usual conditions of working, are described in a catalogue received from Messrs. Clayton and Shuttleworth, Limited, Lincoln. All the engines are of the two-stroke cycle for crude oil fuel which, it is explained, includes any heavy commercial fuel oil, Russian naphtha, gas oil, shale oil and tar oils. The standard horizontal engines, with one cylinder and with one or two flywheels, are made in eight sizes, ranging from 6 to 75 brake horse-power. A series of two-cylinder engines is also made, these engines developing 70, 100 or 150 brake horse-power. In all cases the engines can be adapted for driving electric generators, and for other purposes for which great steadiness of running is essential. Similar engines up to 25 brake horse-power are supplied, mounted on four-wheel trucks for portability. A vertical 8 brake horse-power engine direct coupled to an electric generator, is also illustrated. Self-starters are recommended for engines of 35 brake horse-power and upwards. The cost of working a 12 brake horse-power engine per week of 50 hours is given as 22*s.* 6*d.*, as compared with the corresponding figure of 34*s.* for an engine on paraffin.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

SELECTED ABSTRACTS OF RECENT PUBLISHED SPECIFICATIONS UNDER THE ACTS OF 1907 AND 1919.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, &c., of the communicators are given in italics.

Copies of Specifications may be obtained at the Patent Office, Sales Branch, 25, Southampton Buildings, Chancery-lane, W.C., at the uniform price of 1s.

The date of the advertisement of the acceptance of a Complete Specification is, in each case, given after the abstract, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

ELECTRICAL APPARATUS.

208,895. The M-L Magneto Syndicate Limited, West Orchard, Coventry, and D. K. Morris, West Orchard, Coventry. Electrical Transformers. (5 *Figs.*) December 8, 1922.—The invention relates to electrical transformers for use in radio or other telegraphic or telephonic systems. According to the invention, in an electrical transformer comprising two similarly arranged coil units, each of which consists of a number of primary and a number of secondary turns arranged so that the coil units are separate and face to face with their respective primary and secondary windings electrically continuous, the units are so wound, connected and arranged that the capacity existing between the core and the windings of the coil next thereto is reduced to an extent (or even eliminated wholly) which makes it less than the capacity existing between the adjacent layers of the primary and secondary coils respectively. The twin coil-units have a core A of H-form and a separate magnetic closure thereto, and windings consisting of two similar coil-units B, B^2 arranged side by side on the core A. Each coil-unit consists of a number of primary turns B^3 over which are wound the secondary turns B^4, and the four ends of each unit B5, B6, B^7, B^8 are all brought out on the same face of the unit. The units are wound always in the same sense directly upon the core,

Fig. 1.

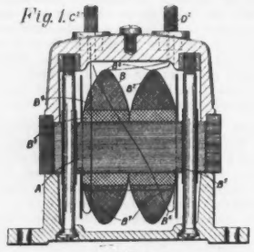
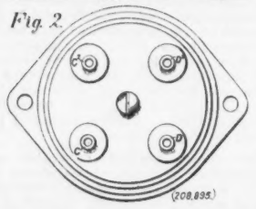


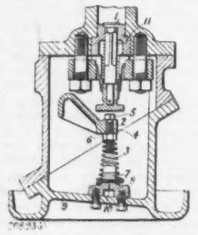
Fig. 2.



and after completion of the first the core is turned end for end in the winding machine to wind the second one, thus bringing the commencements and terminations in each case to the respective ends of the core, at the outside. In the winding of the coil-units, successive layers are separated by thin paper or equivalent insulating material which has been corrugated in a direction transverse to the conductor, and this corrugation provides an approximate air spacing of the layers. The starting end B5 of each primary section is electrically connected to the core A and the other ends to the primary terminals C, C^2. The starting ends B^7 of the two secondary sections B^4 are then coupled together and insulated, while the other two ends B^8 go to the secondary terminals D, D^2. The object of coupling the inner layer of winding direct to the core is that if the core acquired the alternating potential of any other part of the winding, the self-capacity thereby arising between the inner winding layer and the core might easily exceed that of the winding itself. In each coil-unit the successive layers are so diminished in width (axial length) that the primary with the superposed secondary have a "battered" contour in an axial section which becomes narrower as the radius of the coil increases, as is clearly shown in Fig. 1. (*Accepted January* 9, 1924.)

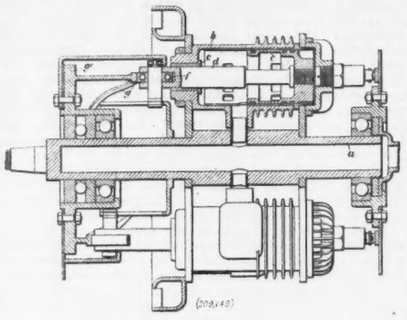
GAS ENGINES, PRODUCERS, HOLDERS, &c.

208,936. C. Day, Stockport. Oil Engines. (2 *Figs.*) January 22, 1923.—In many oil engines the speed is regulated by means of a governor acting through suitable mechanism upon the



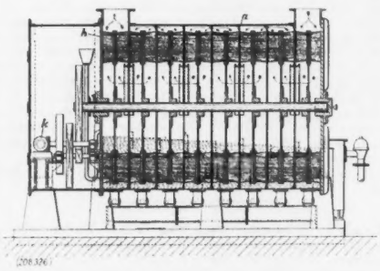
suction valve of the pump which delivers the fuel oil to the cylinder. The invention consists of an arrangement of a spring or springs and/or weighted device which on failure of the mechanism between the governor and the suction valve will substantially reduce the quantity of oil pumped to the cylinder or entirely prevent any being pumped, and will thus quite prevent any dangerous racing of the engine. 1 is the suction valve of the fuel pump (not shown) which supplies fuel to the engine. 2 is a tappet which acts on the bottom end of the valve 1 in such a manner as to hold the valve 1 open a greater or less period of time as may be desired. The tappet 2 is controlled from the governor (not shown). Underneath the tappet and acting upon it a spring 3 is arranged so that if by any mischance the mechanism between the tappet 2 and the governor is broken or becomes loose, the tappet 2 will be forced upwards by the spring 3 and will thus hold open the suction valve 1, and in this way prevent any fuel being delivered by the fuel pump to the engine cylinder. The spring 3 is illustrated as a helical compression spring and is retained in position by a screw 4 screwed into a hole in the tappet 2 and provided with a head 5 adapted to act on the valve 1; the screw 4 is locked in position by a nut 6 and projects into one end of the spring, the other end of which engages a spigot 7 on a member 8 fixed to the casing 9, and is secured to the spigot 7 by means of a split pin 10. The spring 3 is of greater strength than the spring 11, which acts on the valve 1 in the closing direction. (*Accepted January* 1, 1924.)

209,149. F. W. Peters, Kingston Hill, and G. T. Wilson, Kingston Hill. Internal Combustion Engines. (5 *Figs.*) July 2, 1923.—The invention has for its object to provide an improved internal combustion engine of the type wherein the piston rods of two or more pistons reciprocating in cylinders, the axes of which are arranged around and parallel with the axis of rotation, are adapted to slide in longitudinal guides and to work against or upon undulating annular cam surfaces which follow a path parallel with the axis of rotation. An internal combustion engine of the type referred to, and made according to the invention,



is characterised in that the piston rods are provided with rollers adapted to engage with a single main cam plate and reverse cam plate and the spindles of the rollers slide in longitudinal guides adapted to maintain the spindles in a radial position. *a* is a hollow shaft upon which is fixed a series of cylinders *b* provided with pistons *c* which reciprocate in a direction parallel with the axis of the shaft *a*. The piston rods *d* have enlarged ends sliding in guiding bushes *e* in the ends of the cylinders *b*. The piston rods are fitted with rollers *f* adapted to engage with the undulating edge of an annular cam plate *g*, which is mounted upon the side of a cam disc g^1. (*Accepted January* 16, 1924.)

208,326. W. C. Holmes and Co., Limited, Huddersfield, D. M. Henshaw, Huddersfield, and J. Whittell, Huddersfield. Gas Washers. (4 *Figs.*) November 7, 1922.—The invention relates particularly to rotary gas washers or scrubbers of the type in which a number of brush or other devices are arranged upon a rotating shaft and revolve within a cylindrical chamber containing liquid into which the brushes dip as they rotate. The invention essentially consists in housing an engine or motor *k* for driving the shaft of the washer or scrubber together with the gearing connecting it to the washer within an extension

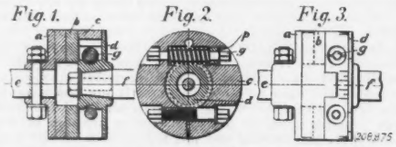


of the cylinder *a*, which forms the body or chamber of the washer, the extension being divided from the washing or scrubbing chamber by a partition *h* through which the driving shaft for the rotor passes in a substantially gas and liquid tight bearing. The outer end of the cylinder extension is preferably entirely closed by hinged or sliding door portions so that the engine and motor are completely enclosed and protected, but access to these may readily be obtained for the necessary attention or adjustment. (*Accepted December* 28, 1923.)

MACHINE AND OTHER TOOLS, SHAFTING, &c.

208,875. C. H. Gale, Winchester. Shaft Couplings. (7 *Figs.*) November 17, 1922.—The invention relates to shaft couplings for coaxial or parallel shafts embodying worm adjust-

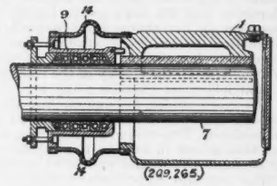
Fig. 1. *Fig. 2.* *Fig. 3.*



ment gear. According to the invention, the worm wheel is toothed round the whole circumference and the worm spindle shaped for rotation by a key or the like at both ends, so that the coupling can be adjusted in any position and through any angle. A flange *d* is firmly attached to one shaft *f*. On the flange *d* is mounted a ring *c* having a space formed in it for the accommodation of a worm *g*. To allow of assembly, one bearing *p* for the worm is arranged to screw in or out of position. The worm *g* meshes with teeth cut in the flange *d*. To allow for locking, the ring *c* is split radially and a locking screw provided. The second shaft *e* has a flange *a* bolted to it. The drive is transmitted through an Oldham coupling *b* having grooves and dogs at right angles engaging respectively dogs on flange *a* and grooves in ring member *c*. The coupling *b* is preferably of rubber, fibre or similar flexible material to absorb shocks in transmission. (*Accepted January* 9, 1924.)

RAILWAYS AND TRAMWAYS.

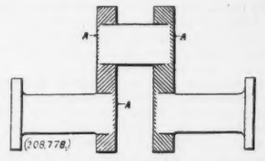
209,265. B. J. Shillito, Manchester, Axle Boxes. (5 *Figs.*) December 6, 1922.—The invention consists in an axle box comprising a bearing box 1 adapted to form a bearing for the axle 7 and receive liquid lubricant, a stuffing box 9 of the adjustable gland type mounted on the axle and displaceable in all directions relative to the bearing box, and a yielding or flexible



arrangement forming a closed connection between the bearing box and the stuffing box, whereby the stuffing box is free to vibrate or be otherwise displaced in all directions with the axle. The yielding or flexible device forms an oil tight joint between the stuffing box and the bearing box. This yielding or flexible arrangement may consist of a yielding or flexible tube 14. (*Accepted January* 16, 1924.)

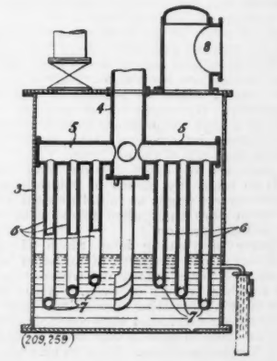
STEAM ENGINES, BOILERS, EVAPORATORS, &c.

208,778. D. B. Morison, Hartlepool. Crankshafts. (4 *Figs.*) September 26, 1922.—The invention relates to the construction of crankshafts. According to the invention, it is arranged that at the flank or flanks of the web or webs remote from the journal there should be formed a solid joint between the pin or shaft and the web or webs or portions thereof. In



the construction illustrated, the face A of the flank comprises a jointless slab, the thickness of the slab in this case being such that the ultimate strength of the pin or shaft represents approximately the ultimate strength of the construction as a whole. The actual method of rendering the pin or shaft and web integral or solid, forms no part of the invention, and it may be accomplished in any known way. (*Accepted January* 9, 1924.)

209,259. C. J. Crighton, Selby, and J. A. Severn, Bolsover, Chesterfield. Steam Accumulators and Regenerators. (2 *Figs.*) November 28, 1922.—The invention has reference to steam accumulators and regenerators for converting an intermittent supply of steam into a continuous flow, and to accumulators and regenerators of the kind such as are employed for converting the exhaust steam from a reciprocating engine into a continuous flow for use in a low-pressure steam engine, comprising a vertical cylindrical vessel 3, into which the exhaust steam is conducted by one or more conduits 6 opening below the level of water therein, up through which water the steam passes to the outlet 8 from the accumulator or regenerator. According to the invention, the conduits 6, whereby the steam is conducted



into the accumulator and regenerator, open thereto in such manner that in operation the steam issuing from the conduits sets up and maintains a constant swirling or circulation of the water in the accumulator and regenerator about the axis thereof. The vertical cylindrical vessel 3 has a centrally-arranged steam inlet 4 from which radiate branches 5, each provided with a series of depending pipes 6, the lower ends 7 of which open below the level of water in the lower part of the vessel. The lower ends 7 of the depending pipes 6 are bent or provided with curved end pieces so that steam issues therefrom tangentially to or circumferentially of the vessel. The pipes of each series preferably open at different levels below the water. (*Accepted January* 16, 1924.)